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NOTES ON THE PRE-PERMIAN PALEOZOICS OF THE WICHITA MOUNTAIN AREA.

J. V. HOWELL

INTRODUCTION

During the past three years a large amount of drilling has been done in the area surrounding the Wichita Mountains of Oklahoma, and many samples have been secured from horizons which do not appear at the surface. It is the purpose of this paper to discuss the characteristics of some of these cuttings and to suggest methods by which these and other samples may be correlated.

In the Wichita Mountain area are found outcrops of Pre-Cambrian, Ordovician and Permian rocks only. Beds of ages intermediate between the Ordovician and Permian outcrop in the Arbuckle Mountains and presumably are present in the Wichitas also, but their presence cannot be demonstrated by surface study. Examination of the comparatively large amount of material available from wells in the region has made it possible to prove the presence of some of these beds, but of others there are as yet no traces.

The notes given herewith admittedly are very fragmentary, but they are presented with the hope that some of the suggestions contained may ultimately assist in the solution of the interesting and difficult stratigraphic problems of the Paleozoic beds of southern Oklahoma.

METHOD OF STUDY

In subsurface correlation the following factors are of service:

1. Lithologic character of the beds penetrated.
   a. Mineralogic and petrologic character.
   b. Texture. Crystalline or non-crystalline. (Tables 1 & 2). Uniformity. Cracked, fresh, decomposed, etc.
   c. Color . Wet and dry. In transmitted light.
   d. Physical character. Hardness, fracture etc.
2. Contents.
   Dry. Fresh, salt or mineral water. Oil, gas, etc.
3. Sequence of strata.
   Stratigraphic succession. Intervals.
4. Thickness of beds.
5. Fossils.

In this brief paper it is desired to discuss the lithologic character of the pre-Permian rocks, and some of the methods which have been found useful in their study. Factors 2, 3, and 4 can be obtained directly from the log or observation at the well. Study of the lithology can best be made on carefully selected samples, examined in a laboratory, which, however, need not contain elaborate equipment.

As a result of the study of a very large number of samples of shales and sandstones from the Wichita mountain region, the writer has been convinced that little reliable information can be obtained from their microscopic examination. Their lithologic character is too variable to permit correlation except within short distances.

The limestones, however, appear to be more reliable, and it is believed that careful study of a sufficient number of samples will compensate largely for the time thus spent. In such study it is essential to follow a definite plan, apply to each sample the same tests, and so to organize the resulting data that they will best express the relationships of the various beds. Haphazard study is not only discouraging, but may lead to serious errors.

The examination of samples may conveniently be divided into three stages:

A. Superficial examination of cuttings or fragments with a hand lens or low power microscope. This should bring out:

1. Color, luster, fracture.
2. Presence of loose fossils and their identification.
3. Selection of representative pieces for thin sections.
4. Recognition and removal of extraneous material.
5. Presence of sand grains, chert fragments, pyrite, glauconite, etc., which may be included in the limestone.

B. Study of the thin sections.

1. Preparation of the section. If a large number of sections is to be studied a motor driven lathe for grinding will quickly pay for itself in time saved. However, excellent sections can be made by hand.

   Select a fragmnt, preferably somewhat flattened, and polish one side. Cement this flat surface to a slide by means of dry Canada balsam, using a small quantity of the balsam melted over a flame. With a six inch mill file reduce the fragment to a thickness of about 2 mm.—experience alone will show when to stop—then grind carefully on a small carborundum knife-stone until the texture of the slice can be readily seen on examination under the microscope. Complete the grinding on a razor hone, and make the section as thin as possible. All of these operations can best be carried out with dry material, and no water should be used, as it tends to soften the limestone and make it disintegrate. When the slide has been cut to the required thinness (.07 mm. is sufficient), it is mounted in balsam in the usual way. An average limstone chip can be made into a slide by this method in 10 to 15 minutes. With a grinding lathe the time can be reduced one half.

2. Study of the section. While a petrogrophic microscope is desirable it is by no means essential. Excellent results may be obtained with either the ordinary microscope or with the binocular type. The latter is preferable owing to its convenience for preliminary examination and in searching for fossils.

   a. Texture. It has been found that, when properly interpreted, the texture of a limestone is one of the best diagnostic characters. However, the wide variations of texture in different limestones is not generally recognized, and is not as readily described and recorded as in igneous rocks.

      A German writer, Hirschwald[1] has studied in great detail the textural range of limestones and from his paper the accompanying illustrations have been taken. Hirschwald's original classification includes a great number of subtypes in addition to those shown, but for the present purpose such refinement seems unnecessary. Subclasses, based on type of

cementing material, percentage of coarse and fine grains, and similar characters may be designated if desired, but should be used with care. It is believed that the twenty-four textural divisions shown, together with such special types as oölitic texture, are sufficient for ordinary work. The types may conveniently be referred to by the letters; while any added subtypes can be designated by numerals, as: A2, B3 etc.

The following types have been selected from those of Hirschwald:

1. Macrocrystalline Limeston. Marble.
   Numbers A to E more or less interlocking, small to medium grains of calcite or dolomite. Grains .75 mm. and larger. The calcite grains usually show polysynthetic twinning ;the dolomite grains do not.
   A. Calcite grains with polysynthetic twinning and with irregular contact surfaces. Grains uniform in size.
   B. Similar to A, but with regular boundaries.
   C. Similar to B, but with grains of unequal size.
   D. Similar to C but with polysynthetic twinning bands curved, due to dynamic action. Interstitial filling of smaller, broken grains.
   E. Strongly deformed calcite grains without sharp boundaries. Curved twinning bands. Recemented kataclastic structure.

2. Mesocrystalline Limestone.
   Numbers F to L. Grains .25 to .7 mm. diameter. Calcite grains seldom show polysynthetic twinning. Often have siliceous or argillaceous cement.
   F. Incompletely intergrown, mesocrystalline grains with microcrystalline cement.
   G. Incompletely intergrown mesocrystalline grains cryptocrystalline cement.
   H. Isolated mesocrystalline grains in a microcrystalline groundmass.
   I. Isolated mesocrystalline grains in a cryptocrystalline groundmass.
   J. Isolated mesocrystalline grains in a pelitomorphic groundmass.
   K. Incompletely intergrown mesocrystalline grains with argillaceous or siliceous cement.
   L. Predominantly mesocrystalline grains with carbonaceous material surrounding the sharp bordered grains.

3. Microcrystalline Limestone.
   Numbers M to Q. Grains .01 to .1 mm. in diameter. Crystalline texture recognizable only under the microscope.
   M. N. Uniform texture, crystal boundaries sharp, wholly microcrystalline. N shows refilled fracture.

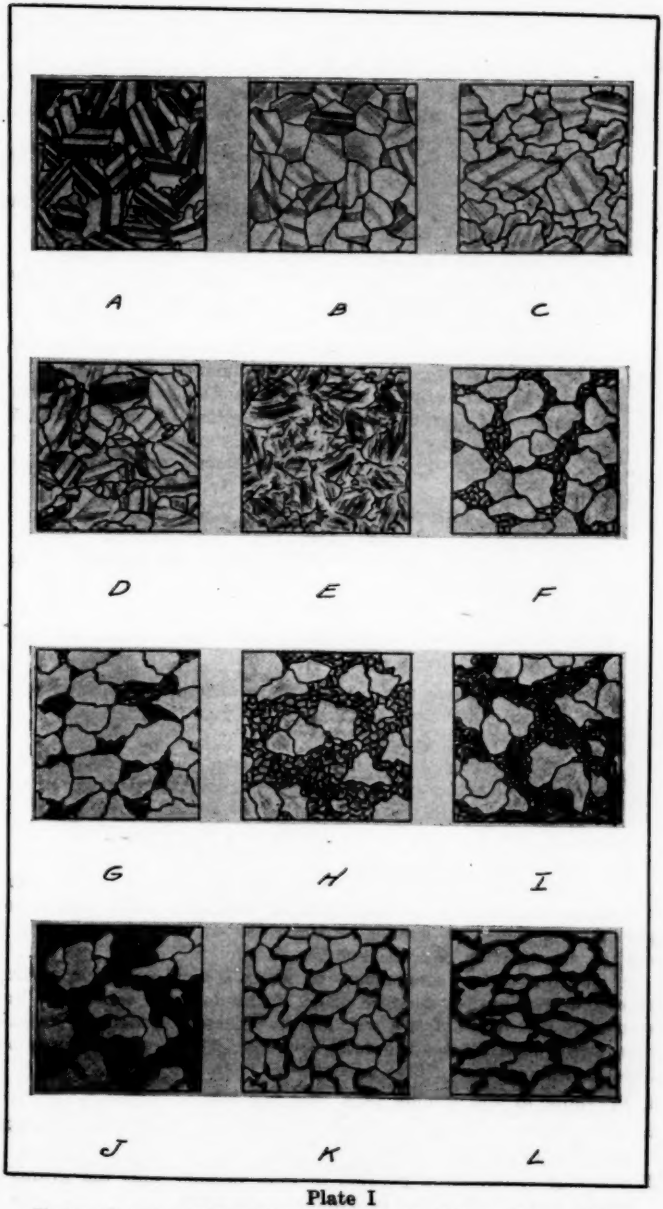


Plate I

Textural types of limestones, as seen in this section. After Hirschwald.

O. Incompletely intergrown microcrystalline grains with siliceous or argillaceous cement.

P. Chiefly microcrystalline but with some areas of cryptocrystalline material.

Q. Chiefly microcrystalline but with proportion of cryptocrystalline larger than in P.

4. Cryptocrystalline and Pelitomorphic Limestone.

Numbers R, S, T. Under very high magnification (400x-600x) the texture is shown to be crystalline.

Pelitomorphic limestone consists of an aggragate of the finest calcite grains (.003-.005 mm. diameter) whose boundaries cannot be recognized except in polarized light. Under the ordinary microscope it appears as a fine granular aggregate.

R. Prevailing cryptocrystalline, subordinately microcrystalline.

S. Prevailingly cryptocrystalline, subordinately pelitomorphic.

T. Prevailingly pelitomorphic, subordinately cryptocrystalline.

5. Shaly Limestone.

U. Limestone with thin parallel shaly lamellae.

V. Limestone veined with streaks of shale flecked through it, inside of which the limestone is completely isolated to form lenses and nodules.

6. Siliceous limestones.

W. Limestone uniformly permeated with silica. Sometimes shows distinct parallel structure.

X. Limestone permeated by quartz, which has separated out in the form of bunches, streaks and irregular masses.

7. Oolites. Chalk.

8. Limestone composed chiefly of organic debris, fragments of fossils, shells etc., which are not recognizable. If coarse would be called coquina.

C. Determination of Amount of Dolomite in Limestone.

Determination of the amount of dolomite in a limestone by the usual chemical methods involves many hours time, the use of elaborate equipment, and the possession of considerable skill. The average geologist is therefore unable to make use of this character in the routine examination of well samples.

In an effort to find some means by which a rapid and approximately correct detremination could be made of the dolomite content of limestone, use was made of two well known processes, which, in combination, were found to give the desired result. The method may be outlined as follows:

1. Crushing of the sample to a fine powder.

2. Screening with sieves to obtain a product in which all the particles are of uniform size.

3. Staining of the sized product in such manner that the grains of calcite and dolomite can be readily recognized.

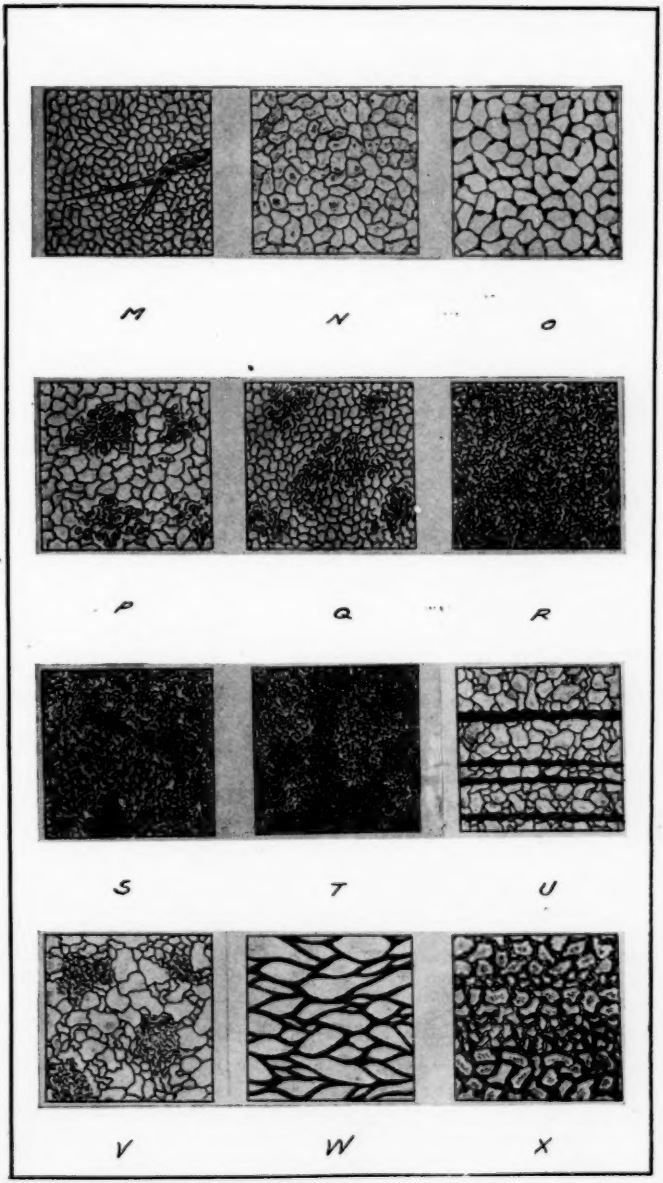


Plate II

4. Counting of the stained grains. The relative numbers of calcite and dolomite grains will closely approximate the percentage of the two minerals in the rock.

Crushing. This may be done in any convenient mortar, but owing to the small amount of material ordinarily used, a 2-inch agate will be found most convenient. The sample should be ground until all will pass the ¼ mm. screen.

Screening. Two screens are necessary, of ¼ mm. and ⅛ mm. mesh respectively. The sieves ordinarily procurable are much larger than necessary, and a more convenient size can be made from a 2-inch tin such as is used by druggists to contain ointment. The bottoms of two such tins are cut out and replaced by small pieces of screen of the desired fineness, which can be purchased from most dealers in apparatus.

All of the sample that passes the ¼ mm. screen and remains on on the ⅛ mm. is placed in a watch glass. The finer material which pass ⅛ mm. is placed in a second glass. There are thus obtained two portions, one of which includes material ranging in size between ⅛ mm. and ¼ mm. and the other being less than ⅛ mm.

Staining. A number of methods have been recommended for differential staining of calcite and dolomite, but the one which is simplest and most effective is that of Lemberg.

To a small quantity of the sized material on a watch glass there is added a few drops of N÷10 $AgNO_3$. The powdered mineral is left in the reagent for two to five minutes and then carefully washed with distilled water from a fine tipped wash bottle. A drop of N÷10 $K_2Cr_2O_7$ is then added and after a few seconds removed by washing.

The powedr is then dried, and examined under a hand lens or microscope. Grains of dolomite will be found to remain unstained, while the calcite becomes a deep red, due to the formation on its surface of a film of silver chromate. The intensity of the stain depends on the length of time during which the silver nitrate is allowed to act. Two minutes is long enough under ordinary circumstances. Thorough washing is essential in order to remove all silver nitrate which fails to react with the calcite.

Counting. A count may be made by sprinkling the stained material on a ruled grating, of a size which will depend on the magnification used. Such a grid may be ruled off on white paper and photographed down to the required size, the negative then being used as a counting plate. A black ground is best

The number of dolomite and calcite grains in five to ten squares is noted, and the proportion of each computed. This proportion is taken as the percentage of each in the original rock.

The counting method given above has been found accurate enough for ordinary work, but if greater refinement is desired, the reader

is referred to Technical Paper 221 of the U. S. Bureau of Mines, where several more exact methods are described. It is best to determine separately the material that passes the ⅛ mm. screen in order to be sure that an exceptionally large amount of either omite or calcite is not contained in either one.

Formation	Thickness	Mineral Character	Texture	Physical Characters
Arbuckle	4,000 to 6,000	Calcite with five to ten per cent dolomite. Argillaceous in places. Stains well.	*B—D* *M, N*	Coarse to medium texture, holocrystalline. Cuttings buff—gray—white. Practically marble. Sections show more or less organic matter, chiefly segregated into rounded or concretionary masses.
Simpson				Some impure limestone with much dark green and gray shale and occasional sandstones,
Viola	500 to 750	Calcite. No dolomite.	*R—S*	Gray color; sharp conchoidal fracture. Dense.
Upper Hunton	Has not been recognized			
Lower	Has not been recognized			
Pennsylvanian	8,000 to 16,000	Calcite only. No Idolomite Some beds show much clayey material.	*Q—T* *Groundmass* *H to J* *on fossiliferous sections.*	Texture generally fine, and crystallizalion indistinct. Much organic material, both in the form of fossils and broken debris, is present in most sections.

DESCRIPTION OF FORMATIONS

Arbuckle Limestone. In the vicinity of the Wichita mountains the petroliferous sands of the Simpson, the lowest known oil bearing horizon, are immediately above the Arbuckle limestone, and in a large part of the area the Pennsylvanian lies upon the beveled edges of the Ordovician beds. Hence the Arbuckle may be considered the "farewell rock,"

below the top of which it is useless to drill, and its ready recognition become a matter of great importance.

The Arbuckle formation has a maximum thickness of about 6,000 feet, all of which is limestone, with only very slight partings of shale. The lateral and vertical variations in lithologic character are relatively slight, and the formation as a whole is remarkably uniform.

Examination of a number of slides from both wells and outcrops has brought out the following fairly constant characteristics:

The texture generally is course, mesocrystalline to macrocrystalline. the range is from *B* to *D* and *M* to *N*, although texture as fine as the latter is exceptional. Occasional clearly definite calcite rhombs occur. The extinction angles of the various crystals are irregular, and samples from near the Wichitas sometimes show many more or less rounded masses of what appears to be organic matter. The fact that this has been gathered into masses may possibly be interpreted as a result of metamorphism. In some samples the material approaches a true marble, but this is by no means the rule. Fossils are extremely rare in sections, although somewhat more common in outcrops.

Megascopically the Arbuckle often is white to buff in color and the cuttings have a granular or "sugary" appearance, much like that of discolored marble.

A characteristic feature of the Arbuckle is the constant presence in all samples examined, of a small amount of dolomite ranging from two to ten per cent. This is readily detected by the methods described above, and is of great assistance in distinguishing the Arbuckle from the Viola, with which it is often confused. The Viola contains no dolomite.

Simpson formation. Although the Simpson has not been definitely recognized in the Wichita area, its presence has been inferred. Oil in the Granite, Gotebo, and Gladys Belle pools is distinctly different from known Pennsylvanian oils found nearby, and the locations of these pools are such that it seems probable the oil has originated in the Simpson. It does not outcrop about the Wichitas, so far as known, and as

no authentic samples are available, no data concerning its microscopic character are given.

In the Arbuckle mountain region the Simpson is composed of dark green or blue shales, rather impure thin-bedded limestones and occasional sandstones. There are many fossiliferous horizons, but the microscopic fauna has not been carefully studied.

Viola limestone. Immediately above the Simpson formation lies the Viola, a thick bed of limestone 500 to 750 feet thick. It is especially important that this formation be not confused with the Arbuckle, since if the Viola be reached at a reasonable depth, drilling through it to the productive horizons may be recommended.

The Viola outcrops near the Wichitas is a few small areas only, at Rainy Mountain Mission, near Gotebo. It has been found in a shallow well on the west edge of Lawton, and in several wells farther from the mountains. In all cases the lithologic characters are very similar.

Fragments of the Viola appears dense, light to dark gray in color, break with a sharp sub-conchoidal fracture, and bear a close resemblance to lithographic limestone. In thin sections the texture commonly is rather uniform, *R-S.* In a few slides a phase resembling *I* has been found, but this seems to be exceptional. No fossils have been found. There are occasional irregular and indefinite rhombs of calcite, usually small.

In no sample tested was there to be found a measurable amount of dolomite, and this lack of magnesium carbonate is believed to be constant.

Hunton formation. No beds corresponding to the Hunton have been identified in the Wichita mountain region.

Pennsylvanian limestones. The limestones, shales and sandstones of the Pennsylvanian have certain distinguishing characteristics by which one acquainted with them can usually recognize them, but to describe these features is far from easy. As would be expected, limestones afford the best means of correlation.

The limestones fall naturally into two classes; those which are composed chiefly of fossils or organic debris, and those

in which fossils are rare or absent. The textures of the two classes are markedly different. In the highly fossiliferous varieties, especially in samples from wells in the extreme southwest part of the area, the texture of the groundmass is *H - J*, while in the unfossiliferous varieties it approaches *Q - T*.

The Pennsylvanian limestones are non-dolomitic, and composed chiefly of calcite, with more or less argillaceous material. The texture generally is microcrystalline or pelitomorphic although some slides show small areas of rather coarsely crystalline calcite. The texture commonly varies in different parts of the same slide, and veinlets and irregularly shaped areas of secondary calcite are frequently seen.

The hardness varies also, but for the most part the limestones are somewhat softer and more readily ground down than are those of the older formations. The color depends chiefly on the impurities present, especially the amount of shale. Greenish and brown tints are common. Radiating masses of aragonite have been seen in a few samples from the north Duncan field.

There are no noticeable evidences of metamorphism. The organic fragments usually are well preserved, and no tendency has been noted for the segregation of such masses of organic material as were noted in the Arbuckle limestone. The non-fossiliferous limes commonly appear granular, rather than distinctly crystalline when examined under low or medium magnification.

The fossils usually found are those of small size, which are not readily broken up by the drill. These have been little studied, many of them are undescribed, and their ranges unknown. The only way in which they can be made of much assistance in correlation is by direct comparison. Ostracoda, foraminifera, echinoid plates and spine fragments, sponge spicules, and small bryozoa are found in great abundance in certain horizons. The thick limestone found in the wells of the Lone Star Gas Co., Sec. 35, T. 6 N., R. 26 W., at 2600-3000; Elmhurst Development Co., Sec. 3, T. 1 N., R. 24 W., from 2650-3100; and Auto Oil Co., Sec., 25, T. 4 N., R. 26 W., was composed very largely of organic fragments, with many

well preserved ostracods, bryozoa, and a few foraminifera. The fossils from the Elmhurst well were submitted to Mr. P. V. Roundy, who considered them to be Pennsylvanian, although he was unable to place them more closely.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

WATER CONDITIONS IN THE URSCHEL POOL MARION COUNTY, KANSAS[1]

By E. F. SHEA

Introduction.
Location and history of development
Structure
    Surtace
    Subsurface
Producing Horizons
    Description
    Analyses
Production
    Methods
    Character and treatment of oil
Water Encroachment
    Occurrence of water
    Early evidence of encroachment
    Method of studying encroachment
    Methods of handling wells
    Effects of water on equipment—Analyses
Effect of water encroachment on well decline
Conclusion

INTRODUCTION

The data contributed in this paper were obtained while making a study of water conditions for the Amerada Petroleum Corporation on their D. F. Urschel lease in the northwest quarter of section 21, Township 21 South, Range 5 East in the Urschel pool. Some of the facts brought to light seemed to be of general interest and at the suggestion of Dr. Sidney Powers, Chief Geologist, these facts as interpreted are here presented.

The surface structure contour map accompanying this paper was made by C. R. Thomas prior to the drilling of the discovery well. Thanks are due to Dr. Powers, Miss Dollie Radler, and others in the Geological Department of the Amerada Petroleum Corporation for their assistance and helpful suggestions in the preparation of charts and manuscript.

[1]Published by permission of the Amerada Petroleum Corporation.

LOCATION AND HISTORY OF DEVELOPMENT

The Urschel, or Florence-Urschel pool as it is more commonly called, is the farthest north and east of that group of oil fields, lying immediately to the west of the "Granite Ridge" in central Kansas. The pool is located about 3 miles south and east of the town of Florence in Marion County and occupies parts of sections 16, 17, 18, 19, 20, 21, 28 and 29, T. 21 S., R. 5 E.

The first well within the present limits of the pool was drilled early in 1920 by the Robinson Petroleum Company, on the J. T. Greeley farm in the southwest corner of the southeast quarter of section 18. Pay sand was encountered at a depth of 2,396 feet and the well started off with an initial production of about 150 barrels of oil and considerable water. This well was located on a small surface nose lying to the west of the major structure. Subsequent investigation disclosed the presence of the larger structure in sections 16 and 21 and resulted in the drilling of a well in the southeast corner of the west half of the southwest quarter of section 16 which is commonly considered the discovery well of the pool. This well was drilled by Merriam & Findeiss and the National Refining Company on the D. F. Urschel lease and was completed July 21st, 1920, in sand at 2,306 to 2,318 feet with an initial daily production of 2,928 barrels.

From this discovery, development rapidly extended into the adjoining section. By the close of the year 1921 the pool, with the exception of the extension southward into section 28, had been fairly well defined by dry holes. It has at present a proved area of about 1,500 acres.

STRUCTURE

Surface. The surface structure was determined by plane-table elevations on the beds of the Winfield, Doyle and Ft. Riley limestones and the Florence flint which cap the low rounded hills lying between the tributaries of Cottonwood River, and Doyle and Cedar Creeks. It consists of an anticline with a long curved axis which lies immediately west of the "Granite Ridge arch" and extends from the northeast corner of section 16 through the center of section 21 and into

the northwest quarter of section 27 (Fig. 1). From the center of the south line of section 16 into the closed syncline in the southwest quarter of section 15, there is a maximum

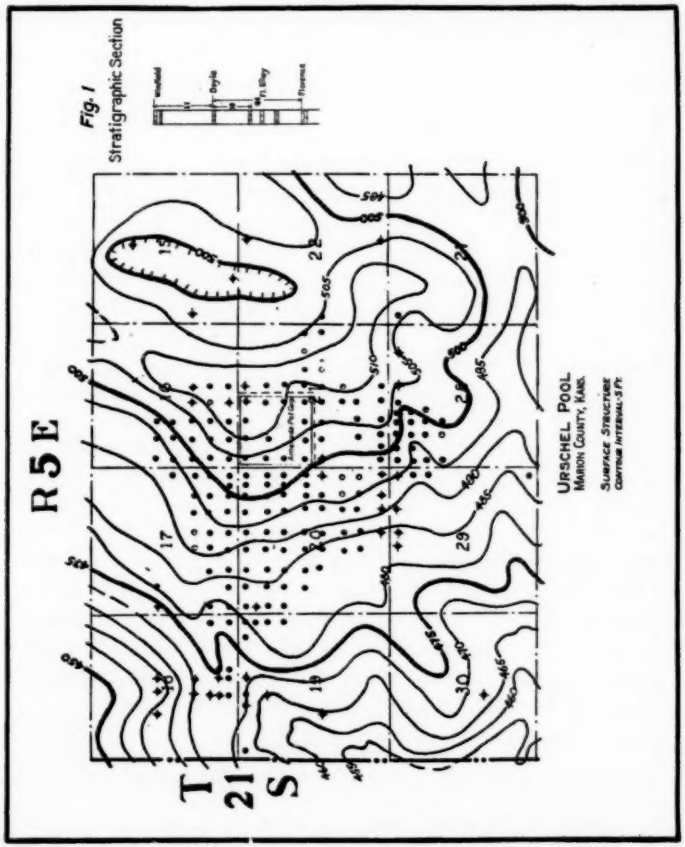


Fig. 1. Map showing the surface structure in the Florence-Urschel pool. Contours drawn on top of the Doyle limestone.

east dip of 13 feet. West of the main axis the structure forms a broad westward plunging nose extending into the east half of section 19. Here it divides to form two secondary axes,

one occupying the north half of section 18 and the other, the northeast quarter of section 30.

Subsurface. The subsurface structure, as defined by datum elevations on the producing horizon, shows very little conformation with the surface (Fig. 2). It consists of an anticline with the long curved major axis extending in a north-south direction from the center of the northwest quarter of section 28 into the northwest quarter of section 21. Swinging westward the axis extends along the south line of section 17 for about a quarter of a mile where it divides, one branch trending southward through the center of section 20 while the other continues westward to the east side of section 18. From this point the dip to the west is abnormally steep amounting to about 75 feet in a half mile. Along the major axis there are a number of irregular "closures." From the center of section 21 to the center of section 22 there is a maximum east dip of about 70 feet on the producing sand. Several minor synclines interrupt the regularity of the major structure and give rise to the local closures. Of these synclines the one in the east half of section 20 is the largest and has the greatest influence on the shape of the structure.

PRODUCING HORIZON

Description. The producing horizon of the Urschel pool which is encountered at a depth of about 2,300 feet is generally considered to be the stratigraphic equivalent of the pay sand in the Covert-Sellars and Elbing-Peabody pools. It is placed in the Tyner formation of the Ordovician[1].

From a study of the character of the "sand," the nature of the production and the results of deepened wells, the writer is led to believe that the Urschel sand may represent an old erosional surface of the Ordovician siliceous limestone.

The thickness of the actual oil bearing "sand" ranges from a few inches to a possible maximum of 12 feet in one well. The average thickness however, probably does not exceed 2 or 3 feet.

The pay "sand" is nowhere a true sand, but is composed

[1] F. L. Aurin, G. C. Clark and E. A. Trager, Notes on the Subsurface pre-Pennsylvanian Stratigraphy of the Northern Mid-Continent Oil Fields, Amer. Assoc. Petroleum Geologists Bull. vol. 5, No. 2, 1921, pp. 47-153.

largely of porous gray to white chert and lime which drills up in rather angular fragments. In the samples observed it varies in texture from finely compact to coarse and unconsolidated grains. Rounded quartz grains are rare. A number

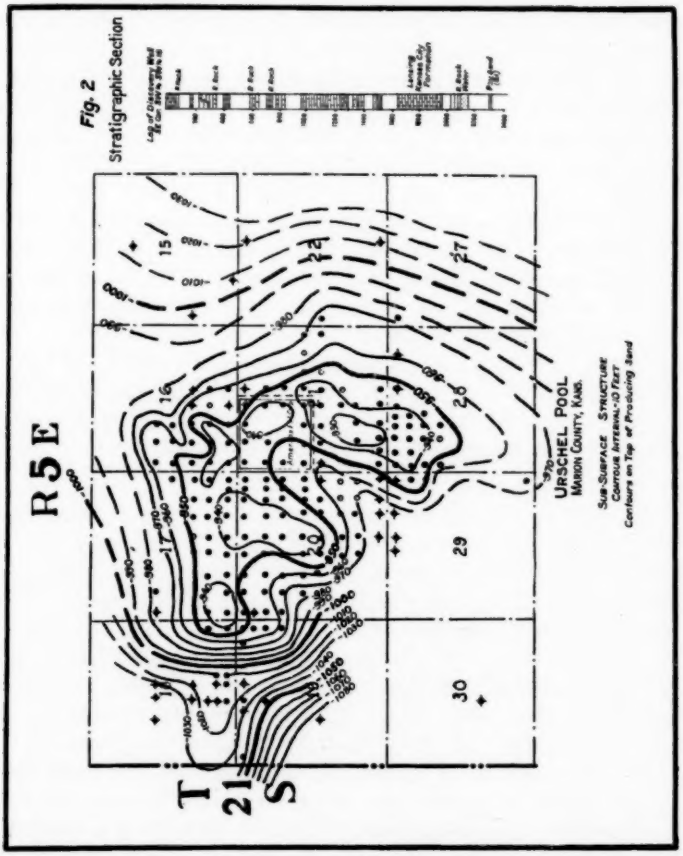


Fig. 2. Map showing the subsurface structure in the Florence-Urschel pool. Contours drawn on top of the producing horizon.

of wells drilled below the pay sand showed this same siliceous lime for several hundred feet and in one well this formation

directly overlies the granite. No measurement of the porosity of the sand was obtained but the evidence all points toward an unusually large amount of pore space.

Analyses. A rather simple quantitative analysis was made of a number of well cuttings. Each sample was carefully weighed, digested in a dilute solution of hydrochloric acid, evaporated to dryness and reweighed, and the residue examined under a microscope. The soluble portion was considered to be calcium carbonate. The crystalline quartz and cherty material were separated under the microscope. The results of some of these analyses are given in the following table:

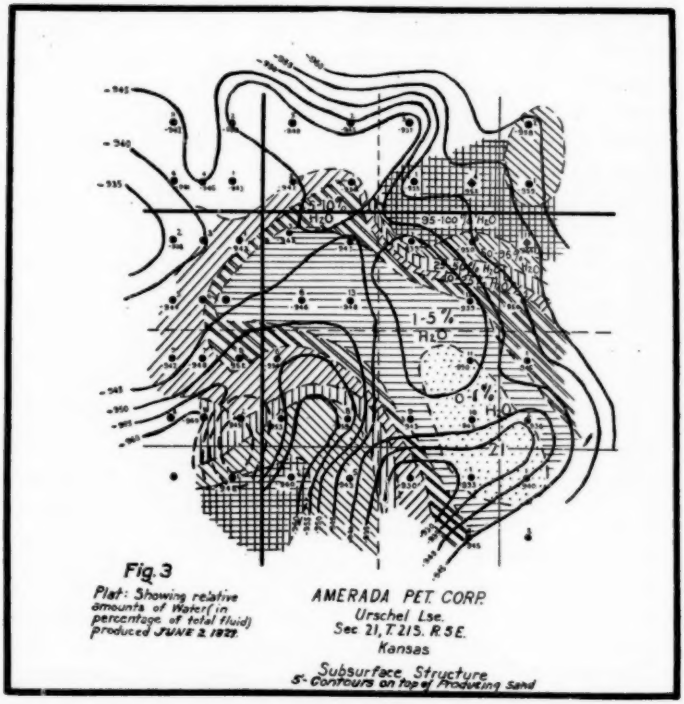
Sample No.	Lime	Chert	Crystalline Quartz
1	13 percent	87 percent	trace
2	51 "	42 "	7 percent
3	8 "	65 "	27 "
4	15 "	84 "	1 "
5	36 "	64 "	trace
Average	24.6 "	68.4 "	7 percent

PRODUCTION

Methods. No gas whatever was encountered in the Urschel pool. The wells owe their pressure entirely to water and very few of them flowed naturally except for short periods under agitation. The only notable exception to this rule was No. 5 well on the Amerada lease which flowed naturally for about six weeks at a rate of over 1,000 barrels daily of pipe line oil. It was then put on the swab for awhile, and later, on the pump but the production declined rapidly. Most of the wells filled up with oil as soon as the sand was penerated and were either swabbed for a time or were at once tubed and put to pumping. Swabbing was a common practice with the earlier wells of the field and some very large daily yields were obtained. Such extreme "pull" on the wells, however, fostered a more rapid increase in water and later wells were tubed and pumped as soon as completed.

The initial daily production of wells showed a rather wide range, from 2,800 barrels in the discovery well to as low as 10 barrels or less in some of the edge wells. Even in offset wells the variation was sometimes marked. On the Amerada

Petroleum Corporation lease well No. 13, just a location away from No. 5, the large flowing well had an intial production of only 60 barrels daily. It was completed several month after No.


95-100 % H2O
1-5 % H2O
0-1 % H2O
21
Fig. 3
Plat: Showing relative amounts of Water (in percentage of total fluid) produced JUNE 2, 1927.
AMERADA PET. CORP.
Urschel Lse.
Sec. 21, T. 21 S. R. 5 E.
Kansas
Subsurface Structure
5' Contours on top of Producing sand

5 and its small capacity was probably due to drainage, which would no doubt be very active in a thin porous sand.

The average initial daily production throughout the field was probably 250 to 300 barrels. Ten acres per well is about the usual spacing. With few exceptions the wells are operated on the unit system. Each well is equipped with an oil engine and pumped on the beam.

Character and treatment of oil. The oil from the Urschel pool is black in color and tests from 33° to 34° Baume. Due to the presence of a large amount of water and B. S., treat-

ment is necessary before the oil can be run into the pipe lines. Steaming and treating with lime is the common practice.

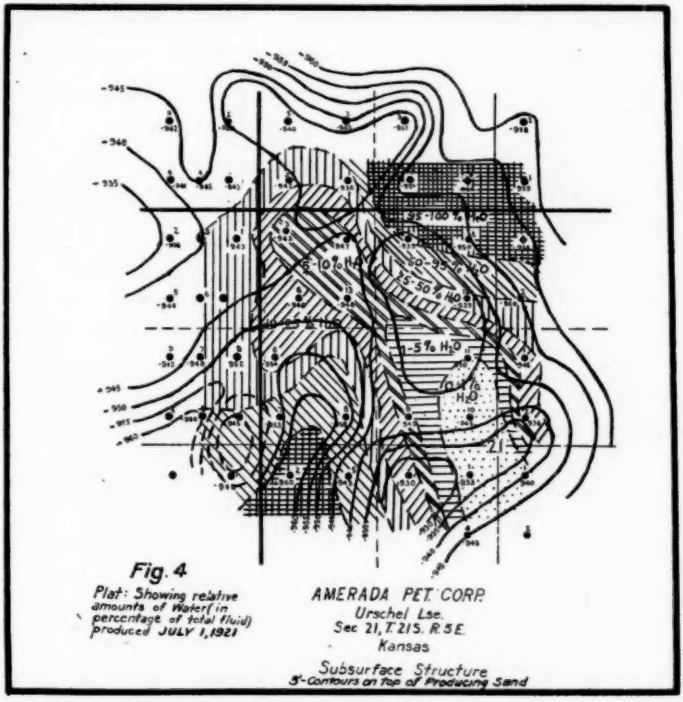


Fig. 4

Plat: Showing relative amounts of Water (in percentage of total fluid) produced JULY 1, 1921

Each lease has its own treating plant capable of handling several thousand barrels of fluid daily.

The Prairie Pipe Line Company and the Sinclair Pipe Line Company each has a line into the field and transport most of the oil.

WATER ENCROACHMENT

Occurrence of Water. The biggest factor to be considered by operators in the Urschel pool and the one with which this paper primarily deals is the problem of water encroachment. It is entirely a problem of edge water, i.e., water within the

pay sand itself, either immediately below the oil on the crest, or entirely filling the sand along the edges of the structure. As proved by experience any well in the pool if drilled below the oil pay would find water in the base of the sand. There

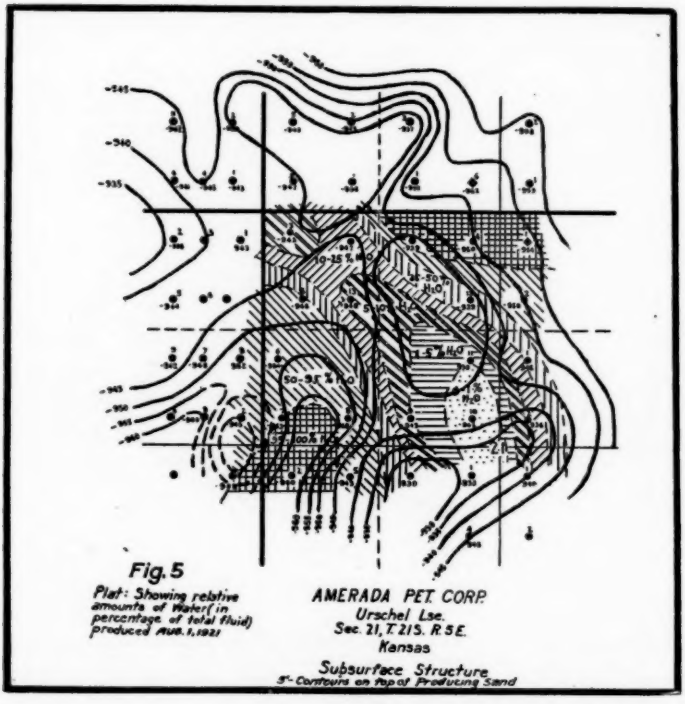


Fig. 5
Plat: Showing relative amounts of Water (in percentage of total fluid) produced Aug. 1, 1921
AMERADA PET. CORP.
Urschel Lse.
Sec. 21, T. 21 S. R. 5 E.
Kansas
Subsurface Structure
5'- Contours on top of Producing Sand

is no apparent break or parting between this water and the oil pay. The separation seems to be merely a matter of gravity and sand porosity.

Early evidence of encroachment. The discovery well penetrated the sand 12 feet and many of the earlier wells drilled near the discovery well penetrated 4 to 8 feet without showing water. However, within a very few weeks, often within a few days, water appeared in these wells and operators soon learned the folly of drilling beyond a foot or two into the sand.

With deeper drilling no increase in oil could be noticed, but the chert became lighter in color and water soon appeared. On the Amerada lease none of the later wells penetrated the sand beyond 18 inches.

In order to determine the elevation of the water with

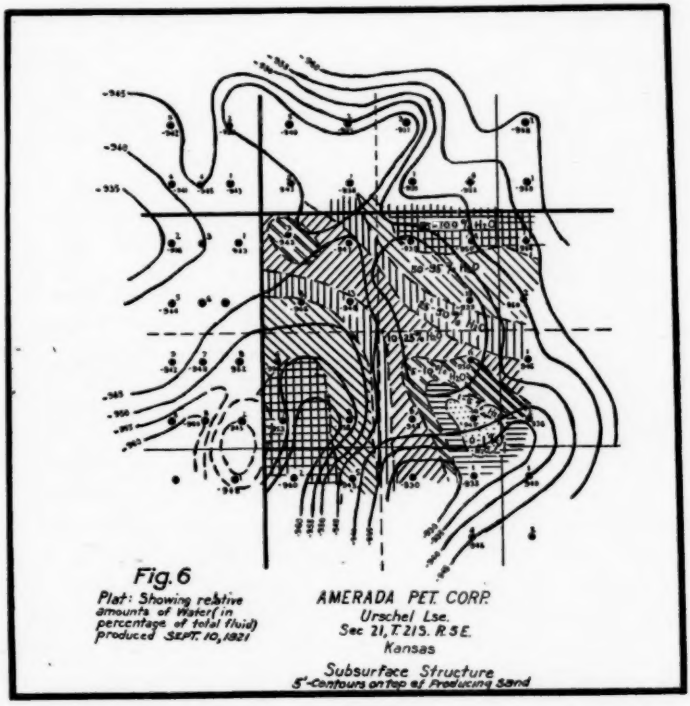


Fig. 6
Plat: Showing relative amounts of water (in percentage of total fluid) produced SEPT. 10, 1921

reference to the structure on the sand, data were obtained which showed the water to exist at higher levels on the east side of the structure than on the west. On the Amerada Petroleum Corporation lease water was encountered in well No. 2 at an elevation of -941, while in No. 1 no water was showing at a total depth of -953. The same condition seemed to exist throughout the structure. This is rather clearly shown on the map (Fig. 2). Production on the east side of

the structure cuts off very sharply above the -960 foot contour while on the west and southwest it extends down in many places to the -980 foot contour. It is noticeable that no production was obtained east of the axis of the surface structures.

Method of studying encroachments. In making a study of conditions on the Amerada Petroleum Corporation lease it was early predicted that there would be more or lesss marked encroachment of the water upon the lease from the northeast and the southwest through the two pronounced synclines. In order best to demonstrate this, a progressive series of charts showing the conditions at thirty day intervals from June 1 to Dec. 10, 19221 (Figs. 3-9) were prepared. The method adopted in constructing these charts was to plot for each well the ratio of water to total fluid produced, as expressed in percentages, and to contour these percentages. The area of equal percentages were emphasized by cross-hatching. This method assumes a regularity not strictly true, because the contours probably should in reality swing in slightly toward each well and bulge outward in the areas between. However, the difference would not be great as is shown by the result of completing an inside location on the lease.

Well No. 14 completed some time after the last chart was constructed (Fig. 9) in the center of the southeast forty acres of the lease started off making 40 percent water, which is about the ratio predicted from its location on the chart.

Two additional factors which might also give a wide variation in results are the sand penetration and the method of handling production, both of which have a direct bearing on the amount of water produced.

The charts were prepared from data obtained on the lease. "Bleeders" were installed at each well and samples of the fluid collected from time to time. The samples were run through a small centrifugal hand separator to separate and measure the percentage of oil, B. S. and water.

With greatly increased percentages of water the samples obtained at the wells are somewhat less accurate in the ratio of water and oil, varying with the condition of the well. For this reason the charts were made allowing a wider range for percentages as the water increased. Except in cases of abnor-

mal amounts the B. S. was included with the water in figuring the percentages.

A study of the charts shows clearly a progressive increase

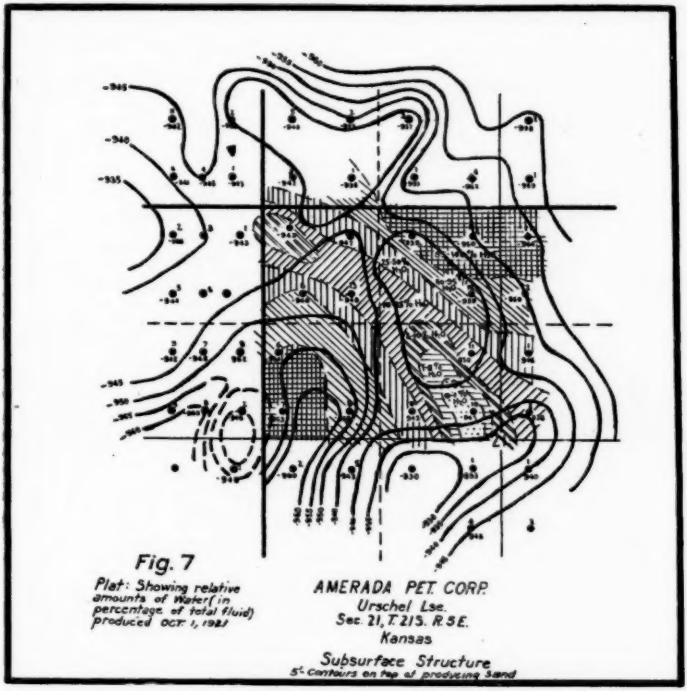


Fig. 7
Plat: Showing relative amounts of Water (in percentage of total fluid) produced Oct. 1, 1923
AMERADA PET. CORP.
Urschel Lse.
Sec. 21, T. 21 S. R. 5 E.
Kansas
Subsurface Structure
5' Contours on top of producing Sand

each month in the amount of water. The areas of small water percentage gradually contract and withdraw around the most persistent wells (Nos. 3 and 10), while the areas of higher water percentage expand and encroach. A comparison of conditions June 1st with those of Dec. 10th (Figs. 3 and 9) summarizes the progress of seven months and shows a very marked increase in the amount of water being produced. Well No. 10, the last to be affected, had commenced to show water. Well No. 2 had been abandoned, while others had increased from a few percent to over 80 percent water.

Data on the wells offsetting the Amerada lease were not always available. Few of the other companies kept any record of the water conditions and the wells were not equipped to collect individual samples. Such general data as were obtained, however, showed the same conditions of encroachment to exist throughout the field. A recent check of some of the

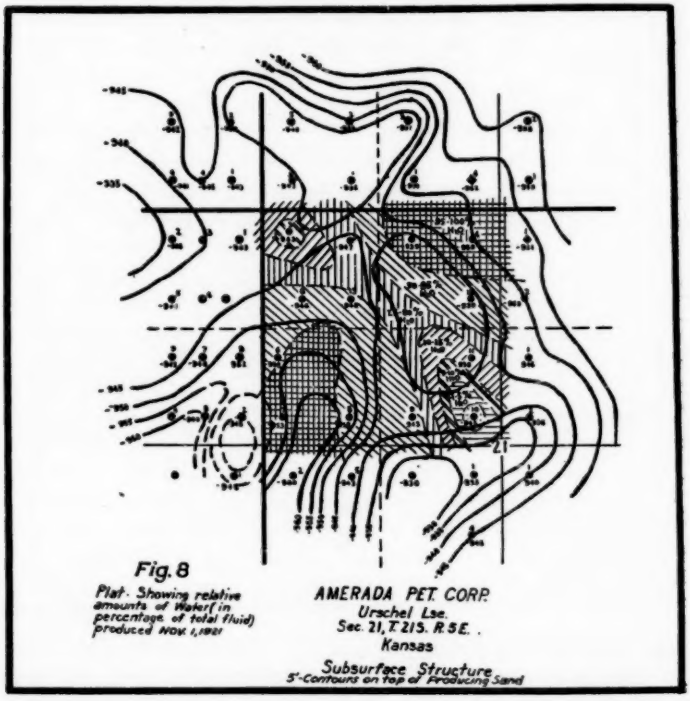


Fig. 8
Plat. Showing relative amounts of Water (in percentage of total fluid) produced May 1, 1922
AMERADA PET. CORP.
Urschel Lse.
Sec. 21, T. 21 S. R. 5 E.
Kansas
Subsurface Structure
5'-Contours on top of Producing Sand

offset wells shows water percentages very close to those anticipated. The writer made a recent survey of the field (May, 1922) and from data obtained has estimated that between three and four barrels of water are being lifted for every barrel of oil produced.

Methods of handling wells. Very few of the wells within the limits of the pool have been abandoned although many of

them produce little except water. In this way excessive pressure is kept off of the good wells so that they may recover more oil. Practically all wells are pumped "straight time"

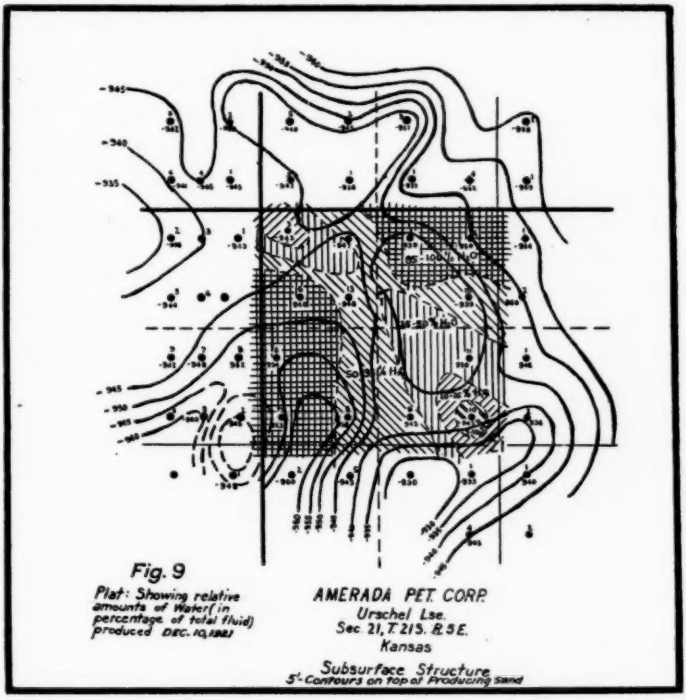


Fig. 9
Plat: Showing relative amounts of Water (in percentage of total fluid) produced DEC. 10, 1931
AMERADA PET. CORP.
Urschel Lse.
Sec. 21, T. 21 S. R. 5 E.
Kansas
Subsurface Structure
5'- Contours on top of Producing Sand

(24 hours a day). Many different methods are being employed to increase production and to reduce the amount of cut oil. Most of the wells are pumped through 3-inch tubing. On some wells, however, 5 inch casing is being used as tubing and the amount of fluid produced greatly increased. Other wells which have a tendency to "pump off" are equipped with 2-inch tubing in order to reduce the production of fluid and enable the wells to be pumped straight time. Adjustments in the length of stroke, the rate of pumping, and the position

of the working barrel are made to suit the condition of the individual well.

Those wells making a high percent of water usually show very little B. S. while the best wells show the effect of encroachment more in an increase in B. S. than in free water. The amount of B. S. is variable and subject to pumping conditions.

The data obtained on the lease of the Amerada Petroleum Corporation were especially useful in the handling of individual wells and in determining the number and location of inside wells.

Effects of water on equipment—Analyses. The water in the Urschel pool is extremely salty and has a noticeable sulphur odor. It has a marked acid reaction as it pits the rods and eats holes in the tubing and line pipe in a very short time. The corrosive effect varies greatly, being much more intense in some wells than in others.

The following analyses of water samples taken from two wells on the Amerada lease were made by Mr. Robert M. Isham:

Constituent	Well No. 8 Parts per Million	Well No. 12 Parts per Million
Hydrogen Sulphide	89.76	6.46
Silicic acid	17.0	16.0
Sodium chloride	11,789.0	12 211.0
Magnesium chloride	753.0	758.0
Calcium chloride	462.0	200.0
Calcium sulphate	405.0	1,032.0
Calcium carbonate	577.0	453.0

In the opinion of Mr. Isham, "the corrosive action of this water is undoubtedly due entirely to the hydrogen sulphide, as the presence of the calcium carbonate, in solution as bicarbonate, precludes the possibility of any free hydrochloric or sulphuric acid." This opinion is substantiated by the fact that water from well No. 8, which has the higher hydrogen sulphide content, shows a much stronger corrosive effect.

EFFECT OF WATER ENCROACHMENT ON WELL DECLINE

The most notable effect of the encroachment of edge water in the Urschel pool is upon the decline in production of indivi-

dual wells. On the Amerada lease alone the wells show a variation in monthly production, decline, ranging from wells with no decline to those abandoned within the first twelve

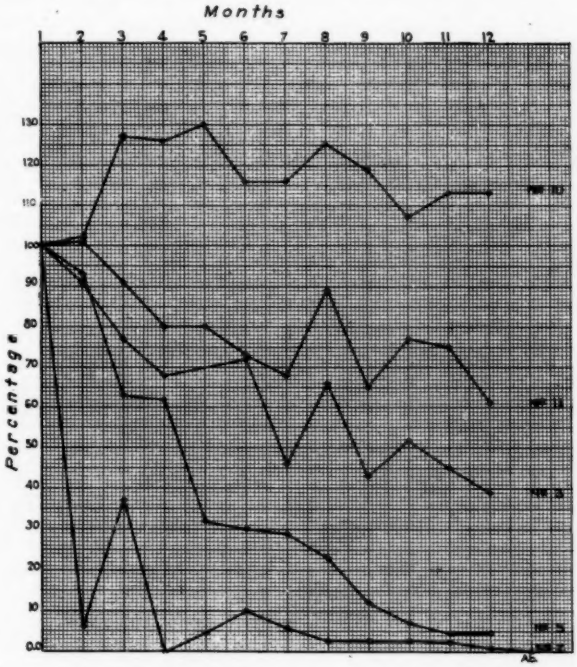


Fig. 10. Chart showing the decline in production by months for several wells on the Amerada Petroleum Corporation lease in the northwest quarter of section 21, T. 21 S., R. 5 E., Florence-Urschel pool.

months (Fig. 10). There is apparently no type decline curve for the pool. A fair average curve might be drawn for a group of wells but the chance of any particular well in the group following that curve is remote.

The decline curves shown on the accompanying chart (Fig. 10) are based on actual production figures for several wells on the Amerada lease. A comparison of these curves with the location of the wells on the charts showing water encroachments (Figs. 3-9) brings out clearly the close connection be-

tween the two factors. The wells which have best resisted water encroachment show a very gradual decline in production and a consequent abnormally high recovery of oil. The edge wells on the other hand show an extremely rapid decline and a low recovery of oil.

The same variation in the decline of wells is known to exist on other leases within the pool.

CONCLUSION

The Urschel pool with a proved area of about 1,500 acres had produced to Aug. 1, 1922, approximately 10,300,000 barrels of oil, an average per acre production of 6,866 barrels. The discovery well in the pool at that time was only 24 months old. The average age of the pool was considerably less than two years. The highest average daily production was obtained during March 1921 when the pool produced an average of 30,230 barrels per day from 85 wells. There has been little change in the number of producing wells since Aug. 31, 1921 when there were 145 wells producing daily 23,000 barrels of oil. Completion since then have just about offset the abandoned wells and the pool in July, 1922, had an average daily production of 7,890 barrels from 150 wells. The early encroachment of water in an oil pool is very commonly looked upon with the greatest pessimism and foreboding and quite often the consequences justify this attitude. When water first appeared in the Urschel pool it was frequently predicted by many interested persons that the pool would never pay out. For some edge leases this may be true, but for the pool as a whole there is no reason to believe that it has not made a very good return on the money invested.

It thus appears to the writer that the encroaching water where properly handled, has aided rather than retarded production. That it has given a more rapid and better recovery than many pools under gas pressure seems apparent from a number of facts. The higher wells show such abnormal persistence—much higher than the average gas pressure well—that we are forced to believe they are recovering much of the oil carried past the lower wells. A recovery of 8,000-10,000 barrels per acre from a sand not to exceed 3 feet in thickness

is quite remarkable. We must either admit the recovery of a very high percentage of the entrapped oil or else assume a porosity entirely out of reason. Some of the higher wells have already recovered from their drainage areas almost as much oil as could be held in the three feet of sand if it were one hundred per cent porous.

Figures for the first half of 1922 show the production to be fairly well settled and at the present rate of decline a total ultimate recovery of approximately 9,000 barrels per acre, or 13,500,000 for the pool, may be expected. The ultimate recovery from the best 10 acres in the field will be at least 30,000 barrels per acre.

ESTIMATION OF RESERVES OF NATURAL GAS WELLS BY RELATIONSHIP OF PRODUCTION TO CLOSED PRESSURE

By PAUL RUEDEMANN[1] and IONEL GARDESCU[2]

Within the last few years the necessity has developed for estimating recoverable reserves on oil and gas properties. In connection with valuations for Federal taxation, it has been stipulated that appraisals must show fair market values based primarily upon representative transactions in the vicinity. This it has been more readily possible to do with oil than gas. In the case of the latter, the transactions are perhaps ninety-nine times out of a hundred limited to sellers, without a competitive market and in consequence, the requisite factor of a willing seller and willing buyer do not exist.

The natural gas industry was, therefore, obligated to obtain a fair valuation by other methods, and left the task to the engineer. Thus, in the short period of about three years the Annual Analytcal method of appraisal has been developed to apply to gas properties. The method consists chiefly in estimating by years quantities of gas to be recovered in multiplying by predicted future price and in discounting,—allowance being made for cost of operating, and the cost of future development on wells not yet drilled.

It is of major importance that the estimation of reserves and the rate of recovery be carried out as accurately as possible, as this has more weight on the final result than any other factor in the appraisal, and is likewise the most difficult to ascertain.

An engineer in appraising oil properties has only one type of data available, production of the wells. This is given at least by monthly records. On gas wells, however, production data at the wells are not available except in rare instances,

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[2] Asst. Appraisal Engineer, Johnson, Huntley & Somers. Pittsburgh, Pa.

and for Federal taxation purposes, appraisal must be according to the value at the well. Not only this, but since production is not metered, tests for estimation are made instead,

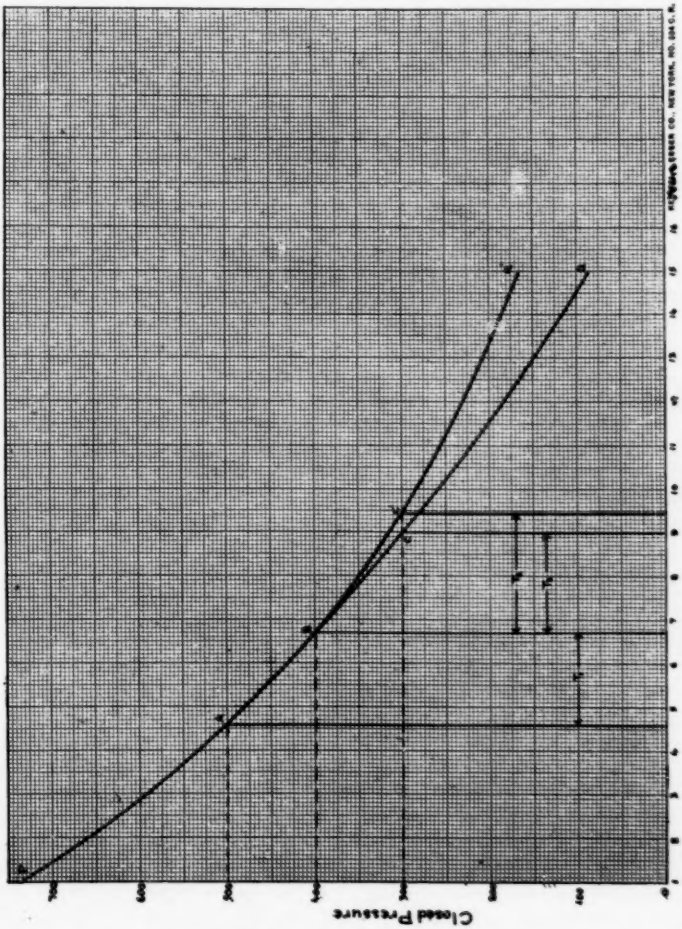

Figure 1.

and this introduces the further difficulty as to the type of tests available. Of these tests, three are in general use: Open

Flow Capacity, Closed Pressure, and Minute Pressure Above Line.

The open flow capacity tests may as well be eliminated as a possible basis for accurate valuation. The senior author, in his experience in appraising many gas properties, has found few with sufficient tests of this type to warrant their use and the method is being rapidly discarded for more economical ones. In any event these tests can be used with greater ease than perhaps any others, and where no closed (rock) pressures or minute pressures are available, should form the basis of all estimates. Their application is not the subject of the paper.

Having found only closed rock pressure and minute pressure above line data on every appraisal made, it was necessary to develop a suitable means for determining reserves with these tests at hand. Minute pressure above line tests are adaptable for the purpose to a limited extent only, firstly, because the line pressure is not uniform throughout the well life and second, because the tests furnish an estimate of daily capacity against operating conditions and not actual capacity. This latter fact was demonstrated for one large gas company and was largely instrumental in the development of the more satisfactory method to be described. A number of wells were turned into the line only at times of the year when the closed pressure was favorable to the line pressure. As a result, the effective minute reading were practically the same for many years. The number of wells showing this condition were too great to advise use of minute pressure. In apraisal the consequence is evident, since the size of the well determines future reserves and therefore valuation, with the effective pressure uniform for many years, the valuation would be constant irrespective of age. One case in particular indicated no change in value for fifteen years, or throughout its whole life. The valuation would have been as large at abandonment as at the time of completion. Aside from this objection it must be recognized that the tests are inaccurate. When used collectively and then corrected by an average yield factor, the amounts found by these readings are satisfactory, but as the basis for the whole appraisal they can hardly be recommended

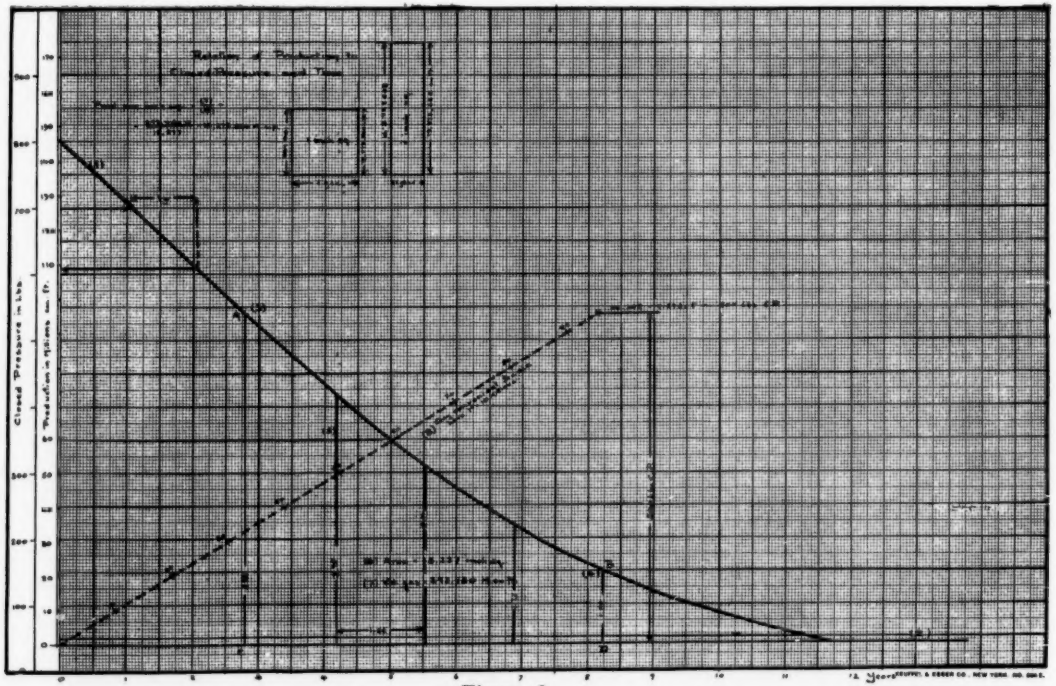

Figure 2.

as productive of results within reasonable accuracy unless carefully considered.

Closed Pressure Tests are most accurate of all. Each well is shut down for short periods every year, making it possible to obtain tests as economically and accurately as desired. But closed pressure is not readily convertible to production, and for valuation we must have the amounts of gas in some unit of cubic feet. An endeavor to find the relation between decline in closed pressure and production brought about the development of the method herein discussed. Previous to this time it has always been assumed that volume of gas in a well is proportionate to closed pressure and therefore production is proportionate to decline in closed pressure. The same assumption is made for the formula given by the Internal Revenue Bureau for use in computing gas depletion. It is based on the relation of pressure decline to total pressure available, which is presuming uniform production per pound decline throughout the life of the well. This is not in accord with Boyle's law, for the amount of gas decreases in a well instead of remaining constant. Further, the volume occupied by the remaining gas is constant in the case of the well, except for water encroachment while in the other case it varies with pressure. The original method, or rather the method now in use, is being called that of Constant Production to the Pound Decline, and not Boyle's method. For convenience the initials C. P. P. D. are substituted when referring to it.

By the use of the theory of constant production per pound decline all the variables incident to gas accumulation and extraction are entirely ignored, and the rate of production recovery is taken in relation to decline in closed pressure. It remains to prove that so simple a relation does not exist in nature. As a portion of the proof depends upon the purpose and type of decline curve herewith presented, the procedure in constructing the curve will be discussed first, and the proof of validity given thereafter.

The principle on which the curve to be described is based is chiefly that *the areas beneath segments corresponding to closed pressure decline are proportionate to the amount of gas produced.* It is to be noted that in the method outlined, the

relation between closed pressure decline and production is one of surfaces and not of volumes. Had volume been adopted, the theory of C. P. P. D. could be recognized as applying to natural gas. Experience and evidence, however, preclude any such recognition. The variables occurring in nature are too numerous ever to yield a uniform amount of production for each pound of closed pressure decline.

A few of the many factors tending to cause deviation from the theoretical rate are:—

1. A gas reservoir is not a closed container. The commodity is perhaps the most mobile natural resource. The limit of migration zone varies with the physical characteristics of the producing horizon, water conditions, and other interferences.

2. Pressure in the reservoir is not uniform. When flowing, the pressure is least near the well and increases with distance therefrom to a point where influenced by interference with other wells.

3. Gas flows against line pressure, which is not uniform.

4 Water conditions are not constant. The amount of water in the sand varies and consequently affects the production. Encroaching water is likely to drown out a well when the closed pressure is still high.

5. A uniform temperature is required to yield results in accordance with the ideal case. A variation in temperature is not at all likely when during the life of the well, change in pressure and other factors are taken into account.

6. Leakage outside of casing to non-producing sands. This is likely to increase with the age of the well and deterioration of equipment.

7. Vacuum—Gas recovered by vacuum cannot be estimated by closed pressure decline. Wells in this stage seldom show any change in closed pressure even though gas is being recovered.

With such a list of variables, many of which differ with each well and sand, it is not safe to attempt estimates on individual wells. Data had best be grouped and average conditions found. Moreover, for the particular curve to be demonstrated, part of the individual wells produce as follows:—

Sands or Combinations	No. of Wells
1. Fifth	8
2. Gordan and Fifth	10
3. Gordon Stray and Fifth	5
4. Gantz, Gordon and Fifth	3
Thirty Foot, Fourth and Third, etc.	1 etc.

Total 22 combinations—10 sands—71 wells.

Because of the very great amount of work which is required

to estimate future production for each well when the combinations are so numerous, the grouping by pools or geographical divisions was found most practicable. However, it

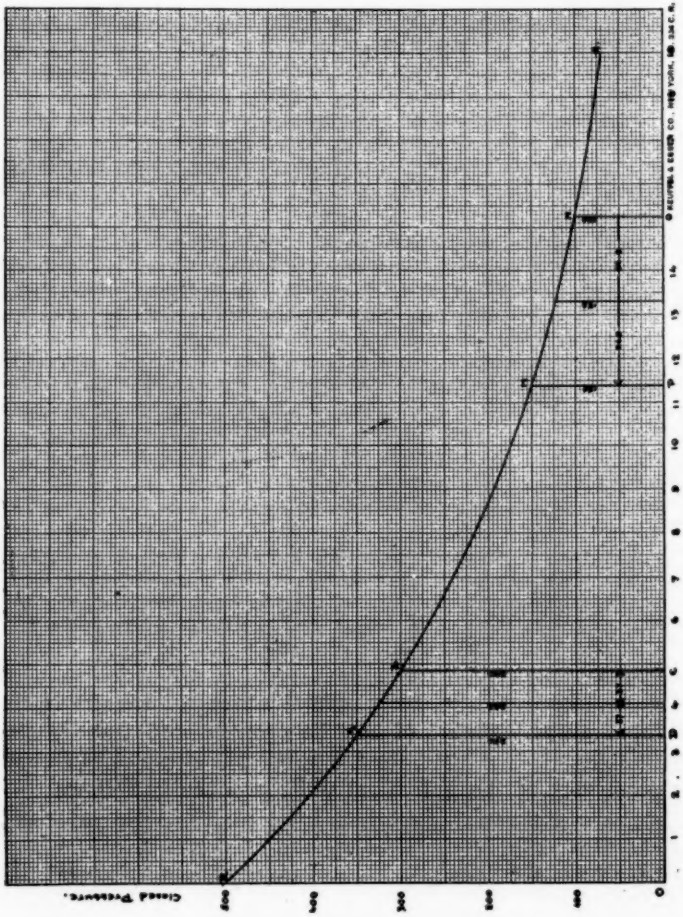

Figure 3.

must not be assumed from this that individual well curves, based on individual well data cannot be devised. This is a problem for the engineer to solve.

Figure 1 is submitted to show that the area corresponding to a closed pressure decline is proportionate to the amount of gas produced, and that volume is not proportionate to the decline in closed pressure.

The line PQ represents the Closed Pressure Decline of a well not in accordance with C. P. P. D. The segment AB is the decline from 500 pounds to 400 pounds, and T′ the time consumed in declining. Through AB is drawn a curve PQ′ of equal area face for constant decline, namely, a curve agreeing with C. P. P. D. Curve PG intersects the 300 pounds Closed Pressure Line at C, and PG′ the same line at C′. Since the curves both go through AB the volume corresponding to the decline will be the same in both cases. Assuming an average closed pressure from A to B of 450 pounds and a resulting effective minute pressure above line of (x), the volume of gas produced during the decline of 500 to 400 can be obtained. The surface representing this volume is designated as ABMN.

By the same procedure the volume corresponding to the decline from 400 to 300 pounds can be determined. This is the effective minute pressure times the volume and the time. The effective minute pressure will be equal in both cases, as BC and BC′ both decline the same amount, the the average closed pressure is 350 pounds. However, the time element affects the volume of gas produced in the period. Effective minute pressure (Y) times volume of hole (Z) times time (T) equals amount of gas produced. Y and Z are equal for each case, but time is different. For BC′ the time is T_2 and for BC it is T_3. Thus, the volume of gas produced by well PQ′ is declining from B to C′ is YZT_2 and well PQ is declining from B to C is YZT_3. The ratio between the volume of gas produced is T_2/T_3 and the same ratio holds for the surface BC′RN to BCON. Therefore, it can be assumed that the surface enclosed by the closed pressure decline is always proportionate to the amount of gas produced, and by ascertaining the relation of one of these surfaces to a known volume of gas, a scale can be adapted. This scale will be true for any surface and volume enclosed by the closed pressure curve.

All references in the outlining of the method are to Figure

2, and are taken up in the order necessary to construct the curve, which is:

1. Closed Pressure Composite Decline Curve.
2. Line of Economic Limit
3. Average Beginning Closed Pressure of Wells.
4. Average Final Closed Pressure of Wells.
5. Vertical Distances.
6. Surface.
7. Volume of Average Sand.
8. Line for Scale Computation.

1. *Closed Pressure Composite Decline Curve.* This curve is nothing more than the usual average or composite curve of a number of wells. The method of constructing this is optional with the engineer. A number of recognized ways are in common use. Some are not practical because of the nature of closed pressure decline data. In all the appraisal work done thus far, satisfactory results have been obtained by using the so-called Segmental Method.

2. *The Line of Economic Limit.* This depends upon the history of abandonment. In the particular case shown, the wells in the region had been abandoned, on the average at forty pounds closed pressure. It is quite possible that in the future, when vacuum is installed, a much lower average will result. Where such is likely to occur, the line can be lowered to the probable average future pressure of abandonment. Since no production takes place below this line it is considered the line of zero production.

3. *Average Beginning Closed Pressure of Wells.* For all the wells used in the construction of the composite decline curve, the beginning closed pressure is listed and the average found. Since it is necessary to have production data, for the period corresponding to closed pressure decline of each well, the readings do not all go back to initial pressure. The average herein was 540 pounds, or 500 pounds above the line of economic limit. The 540 point is indicated on the composite curve as the point of begining of the average well.

4. *Average Final Pressure of Well.* This is the average of the last readings used for all wells included in the composite curve. It is not necessarily the readings as of the last date available, for production must be given, and consequently the

last reading used for some wells is not the most recent. The average was 149 pounds or 109 above the economic limit. The point is marked on the curve as in the case of the beginning closed pressure.

The production for each well is tabulated, as are the number of sands. The results obtained from a table devised to get this information are:—

	No. Wells	No. Producing Sands	Beginning C. P.	Last Reading C. P.	Production all wells for the M. Cu. ft. Period
Total	119	199	64,266,340.05	17,792, 149.05	54,370,850,
Averages	1	1.7 per well			498,940

There is now given the average beginning closed pressure, the average final closed pressure and the production for the period. The production is given for the average well, and for the time indicated by the average decline. For purpose of refinement it is desired, often, to find the production for the average sand, instead of for the average well. All data in this report are reduced to one sand.

It is assumed that the area beneath the segment AB, and above line of economic limit, or ABCD, represents production for the average sand or well. The area has to be calculated. For this, Simpson's rule is used although a planimeter or any other method of obtaining area is satisfactory.

By the rule, the base CD is divided into an equal number of parts, as (5) of Figure 2; the ordinates corresponding to the division points drawn and lengths then found. The formula is:—

$$\frac{1A \text{ plus } 4E \text{ plus } 20 \text{ plus } IN}{3} \quad X \text{ Dist. equals Area}$$

Distance being the spacing of the ordinates. The first (A) and last (N) ordinates are always multiplied by one, the other odd ordinates (O) by two and the even ones (E) by four, the sum is divided by three and the result multiplied by the dis-

tance between two consecutive ordinates. In the example only four equal parts are made and the formula is, therefore:—

$$\frac{1A \text{ plus } 4B \text{ plus } 2C \text{ plus } 4D \text{ plus } 1E}{3} \quad \text{X Dist.}$$

The computation is:—

$$\frac{(5.00x1) \text{ plus } (3.75x4) \text{ plus } (2.71x2) \text{ plus } (1.77x4) \text{ plus } (1.09x1) \text{ x1.36}}{3}$$

equals 15.227 square inches

The average volume per well was found to be 498,915 M cu. ft. divided by 1.7, the average sands per well, gives 293,480 M cu. ft. per sand. This amount corresponds to the surface ABCD or to 15,227 sq. in. The production per inch square is 293,480 equals 19,293. 6 M cu. ft.

On the chart, time in years, and each 100 pounds of closed pressure are one inch apart, making 100 pounds for one year equivalent to a square inch, or 19.273 M cu. ft. Had years been a half inch apart the same volume would be equivalent to 200 pounds, provided the length of the curve represented 24 years and not twelve.

8. *Line of Scale Computation.* Since one hundred pounds is too small to fix the scale, the amount has been multiplied by five. The corresponding production for five hundred pounds is 96,368 M cu. ft. On a scale or a sheet of paper with decimal divisions, a length equivalent to 96,368 M cu. ft., or 9.637 inches is taken. The zero point of the scale is placed at the left end of the line of economic limit and swung around until the 9.637 point is opposite the 540 Closed Pressure point, that is 500 pounds above economic limit. Each inch laid out on the line represents ten million cu.ft. Mark the points, and by horizontal lines construct the production scale along the left margin of the graph. Thus there is given a closed pressure, and a corresponding production scale.

To Read:—A sand with an average closed pressure of 700 pounds for the years is producing at the rate of 126,000 M cu. ft. per year. It will produce 119,00 M cu. ft. the following year and 82,000 M cu. ft. the third year, etc. In the first case the amount shown at 700 is the production for the year, and in the second, one horizontal inch from the intersection of 700

line with the composite decline curve is the production, and so on for each successive year.

Where no closed pressure is given for a well the rate of

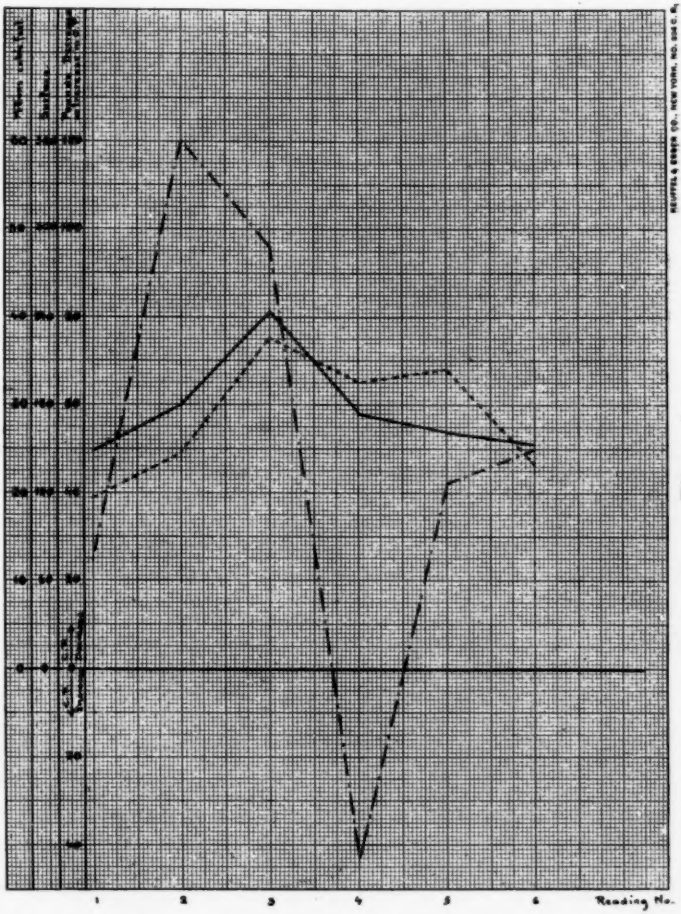

Figure 4.

production for any year will serve equally well. It must be remembered that the production used in constructing the curve

is on minute pressure above line estimates, and any results obtained are subject to correction to the equivalent of metered production. The same holds true where open flow tests are used to make this estimate. If meter readings are available, no correction is of course required.

PROOF OF METHOD

The proof necessary, in order to substantiate the contention that volume is not proportionate to decline in closed pressure, must show: (1) The area relation for well of constant production per pound decline. (2) That for individual wells the relation of production to area embraced by closed pressure change is more accurate than that of constant production per pound decline. (3) That total estimated future production of wells by curve corresponds on the average with the actual production recovered from the wells. (4) The rate of return of production by curve corresponds with rate by actual wells. The proofs will be taken up in the order outlined.

Proof 1. *Area Relation for Well of C. P. P. D.* The first essential in this proof is to develop a curve which declines consistently with the rule, and therefore produces the same amount of gas for each pound decline. Having found such a curve, the next step is to prove that the areas beneath two segments of the curve, each segment representing the same number of pounds decline, are equal. In the discussion to follow the C. P. P. D. curve is constructed, then the area is computed to show its relation to production.

Assume a well of volume V_0 containing gas at a pressure P_0. The gas is allowed to escape. The amount of gas escaping is proportionate to the effective pressure of the gas in the vessel to the size of the orifice, the nature and viscosity of the gas, the friction between the orifice and the flowing gas, ect. These latter are all small quantities and can be considered as constant factors, the sum of which is K. The amount of gas escaping per unit time is therefore KP.

After one unit of time, the pressure has declined from P_0 to P_1 due to the amount of gas, KP, which has escaped, and based

on the fact that the total quantity V_0P_0 is constant. Therefore:

$$V_0P_0 = V_0P_1 \text{ plus } K\,P_0$$

or

$$P_1 = \frac{(V_0 - K)\,P_0}{V_0}$$

V_0P_0 equals V_0P_1 plus KP^0 is a general formula. This can be used further for the second unit times as:—

V_0P_1 equals V_0P_2 plus KP_1

P_2 being the pressure after the second unit of time as resulting from the new amount of gas escaped KP_1.

$$P_2 = \frac{V_0 - K}{V_0} \text{ X } P_1 \text{ or } \frac{V_0 - K}{V_0} \text{ X } \frac{V_1 - K}{V_0} \text{ X } P_0$$

$$P_2 = \frac{(V_0 - K)n}{V_0 \quad n} \text{ X } P_0 = \frac{(1 - k)n}{v} \text{ X } P_0$$

Let P_0 equal 100 pounds, V_0 equal 1000 cu. ft. and K 100, using the formula:

$$P_n = \frac{(1 - K)^n\ P_0}{V_0}$$

We get the following data for P:—

P_0 equals 100
P_1 equals 90
P_2 equals 81 etc.

In the Closed Pressure Production Method it has been assumed that the amount of gas produced by a well depends on the typical condition of the well's decline and is *proportionate to the area* enclosed by the closed pressure line, the bottom axis and the two ordinates corresponding to the beginning and final closed pressure. And this is true for any kind of actual decline curve.

By the C. P. P. D. rule for 10 pounds closed pressure decline there should correspond the same amount of gas, whether the well decline from 70 to 60 or from 40 to 30. By the Closed Pressure Production Method, the surfaces are proportionate to the volume; the surfaces should therefore be equal for the same decline.

The closed pressure decline curve calculated according to the rule has a definite shape.

$P_n = K^n P_0$ is the typical logarithmic curve.

Furthermore, the curve is asymptotic to the zero closed pres-

sure line. It is possible to change K to P^0 and get a series of C.P.P.D. closed pressure decline curves. But if two points of the curve are known, the whole curve is perfectly definite,

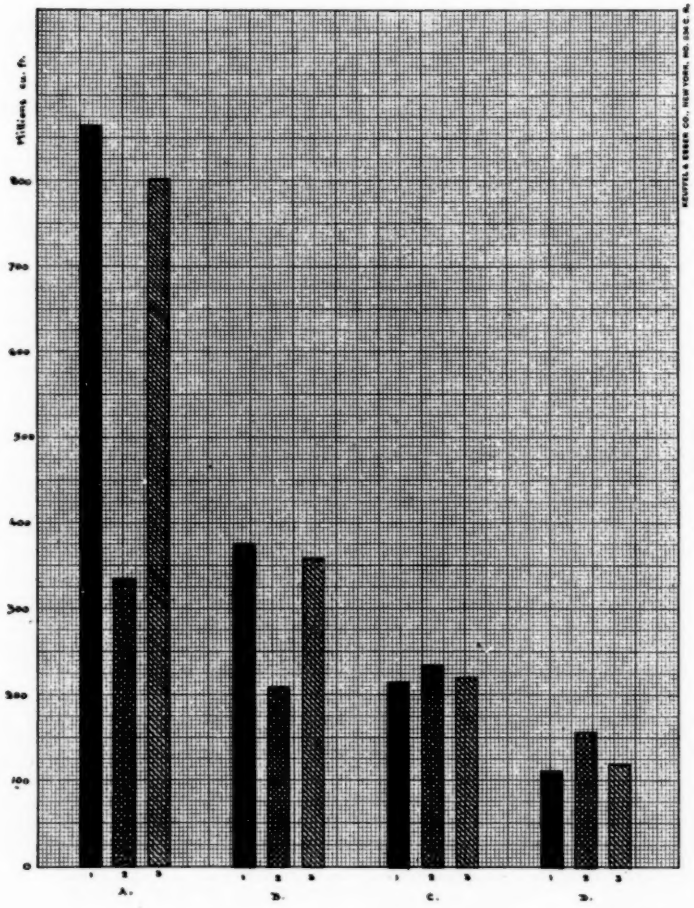

Figure 5.

and a definite value for K and P is obtained. Under such conditions, if it is known that the well decline from 70 to 60

pounds pressure in .74 years, the remainder is readily ascertained. By formula it has to decline from 60 to 50 in .85 years. Does it have to decline in such time by the simple fact that it declines from 70 to 60 in .74 years? Ten wells each declining from 70 to 60 in .74 years will decline from 60 to 50 in ten different ways. And also, the production is different for each of these wells because the time to decline is different. Moreover, it is shown by the Closed Pressure Production Method that there is strong relationship between the production and the time of decline, and the shape of the decline curve.

Proof 2. *For individual wells the Relation of Production to area by Closed Pressure Change is better than that of Constant Production the Pound Decline.* Although the individual well data are likely to be incorrect, they are herein used to demonstrate the relation surface bears to change in production.

A number of wells have been taken, and production for varying periods of decline determined. Given these closed pressure declines and corresponding production, estimates of reserves per unit were made by th C.P.P.D. method and by the area method. For each method the same information is taken as a basis. An economic limit of forty pounds is applied to both.

The final results in the table are obtained by comparison of estimates for the short periods of decline with the average of the whole. In any estimation of reserves, be it by the amount per pound decline or unit surface, the amount must necessarily be an average of the whole.

The details in getting the results are too lengthy to describe in this paper. They will be submitted on request to any who are interested.

The graph, Figure 4, shows one case. It merely indicates a strong relation between area and production. In nine cases checked it was found that the area relation was many times more accurate than the assumption of uniform production per pound decline.

Proof 3. *That the Total Estimated Production of Wells by Curve Corresponds, on the Average, with the Actual Pro-*

duction of the Wells. An effort is here made to show that the estimate future production of a number of wells, as read from the curve, compares favorably with the amount of gas actually recovered from these wells.

To do this, three counties in West Virginia were chosen at random. Accurate production and closed pressure records were obtained and the following procedure was carried out: (1). Closed Pressure Production-Composite Decline Curves, were made according to the procedure outlined in this article. (2). Given the initial closed pressure of a number of wells as of an early date, an estimate was made of their probable future, and the amounts tabulated. (3). For the same wells given in (2) the actual production for the life of the well was totalled. Where a well was not yet completely exhausted, allowance was made for the remaining production by estimating from the curve. This is, in most cases, but a small per cent of the amount already extracted. (4). With the same data used in constructing curves in (1), the amount of production per pound decline was found and the ultimate reserves secured by this method of estimation.

Here is a comparison of the final results, showing how much estimation by area method and C.P.P.D. varied from the actual ultimate production:

County	District	Percent Error Area Method	Percent Error C. P. P. D.
Taylor	Booth's Creek	7 High	40.7 High
Tyler	Centerville	3 High	11.5 High
Lewis	Courthouse (Wells over 500 lbs.)	7.1 Low	61.4 Low
Lewis	Courthouse (Wells over 500 lbs.)	4.4 Low	44.4 Low

Wells of above and below 500 lbs. were taken in one county to see if size would affect the results.

It is certainly apparent from the above facts that production is not proportionate to decline in pressure. The error is far too great to warrant favorable consideration of the method. In fact, known errors of possibly sixty percent, as in the case of one county, are absolutely prohibitive. To attempt an appraisal with the main premise no more than a guess is indeed careless and would lead to unreliable results.

Proof 4. *That Rate of Return of Production by Curve Corresponds, on the Average, with the Actual Rate.* The engineer, in any valuation, is interested to know whether (1), the total estimate of reserves is within reasonable accuracy,

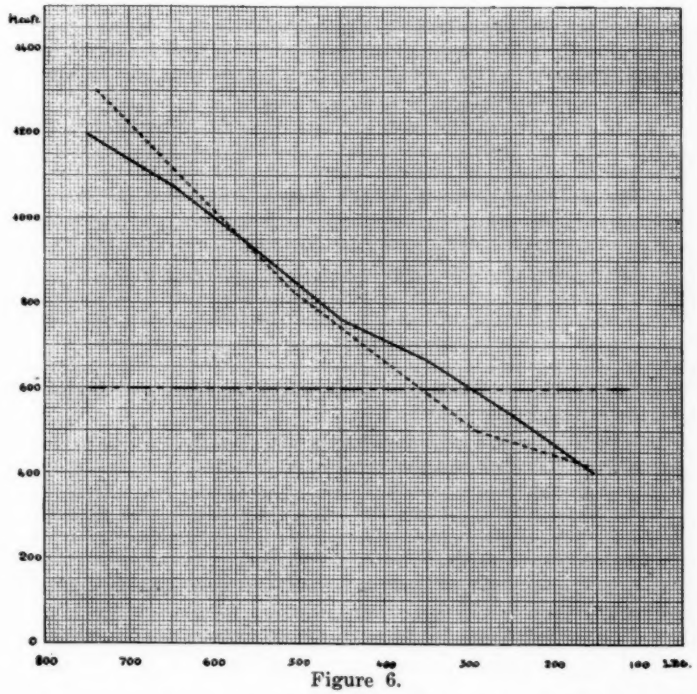

Figure 6.

and (2), whether the rate at which the reserves are calculated to be returned is correct. Proof of the former has just been demonstrated. The latter is of great importance, as present value of a well depends upon the future price, operating cost and discount. Thus to place more production in any one year than is properly assignable to it would cause the amount in error to be wrongly priced and discounted.

To prove the validity of the curve in respect to rate, the production per pound decline in various stages of well life

was examined for a number of wells. Then a comparison was drawn, with the amount the curve indicates as production per pound for each period. It has been found that the production per pound during a well's life may decrease, increase, or both, or it may be nearly constant. By its shape the composite decline curve controls the rate at which the gas is returned. It is of course, a theoretical one and made up of averages.

In Figure 6, is given the estimated production per pound loss in various stages of a well's life as predicted by the composite decline curve. For comparison the actual production of wells in the field is given in a similar manner. The dot-dash line represents rate of return estimating an assumption of uniformity of production per pound loss. This check shows a remarkably analogy between the estimates by the curve and the actual condition.

CONCLUSION

For the region under consideration, the various proofs have demonstrated that:

(1) The relation of production to closed pressure is not uniform except in accidental instances.

(2) The ultimate reserves as estimated from the composite curve herein recommended are within reasonable accuracy for use in annual analytical appraisal work.

(3) The estimate of future production by years from the composite curve would, on the average, correspond with the actual production.

These essentials must not be overlooked in an appraisal. The foundation for any valuation report is the estimation of expected future returns. An erroneous prediction of reserves makes unnecessary any subsequent refinements. In fact, if the rate of return is not definitely ascertainable, a valuation by using yearly production amounts is hardly justified.

On account of the great divergence in "pull," sand conditions and other factors incidental to the amount and rate of recovery it is better to be pessimistic over the results obtained in this paper. Rather than assume predictions based on a Closed Pressure Production Curve as infallible, it would be

better to make checks and determine the applicability of the method for the region under examination. It is hoped that this paper will serve to develop methods of estimating reserves for gas wells which are reliable and adaptable to the conditions prevalant in the operation of natural gas properties.

It is felt that in natural gas estimations, one must, because of the nature of the records and the custom in operating wells, resort to averages taken from wells producing under similar physical conditions. Perhaps with further research it will be possible to apply correction factors to individual well data which will make possible the prediction of future reserves in gas as well as in oil. However, for the present enough experiments have not been performed to demonstrate a feasible individual method and therefore, an average method of proven capabilities must be the foundation for all valuations.

CERTAIN RELATIONS BETWEEN PRODUCTION AND STRUCTURE IN NORTHEASTERN OSAGE COUNTY, OKLAHOMA

BURTON HARTLEY[1]

Investigation extending over several years, of the northeastern part of Osage County, Oklahoma, the adjoining portions of Chautauqua County, Kansas, and Washington County, Oklahoma, have brought to the writer's attention a great lack of uniformity in the relation of oil and gas production to structure. To date most geologists in casually referring to the area and attempting to explain the idiosyncracies of oil accumulation have leisurely dismissed the question as a matter of "lensing the sands." While such a condition probably does exist there appear in numerous instances to be a number of more fundamental reasons for the irregular occurrence of oil pools.

Production in this area is almost entirely confined to the section above the "Oswego" lime and a brief enumeration of the sands and limes, their occurrence and correlation will be given.

The "Big" lime (Oolagah), is in reality made up of two limes, the Pawnee and Altamont of the Kansas section, separated by the Bandera shale. Progressing south the shale thins rapidly and these two limes converge, until in T. 27 N, R. 12 E., Oklahoma, they are separated by a few feet of shale locally turning to sand. In the interval made up by the Bandera shale a productive sand generally occurring directly underneath the Altamont lime is known as the Hancock sand in Chautauqua County, Kansas, and as the Weiser sand in Montgomery County, Kansas. This sand apparently carries only water in Osage County.

About 100 feet above the Altamont lime is the Lenapah or "Little" lime. The interval consists of the Nowata shale and carries the most productive sand of the area. This sand has

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various names in different localities. In Washington County it is known both as the Ramsey and Wayside sands, in Chautauqua and Osage Counties as the Peru sand. This Peru sand should not be confused with the Peru sand of the south-

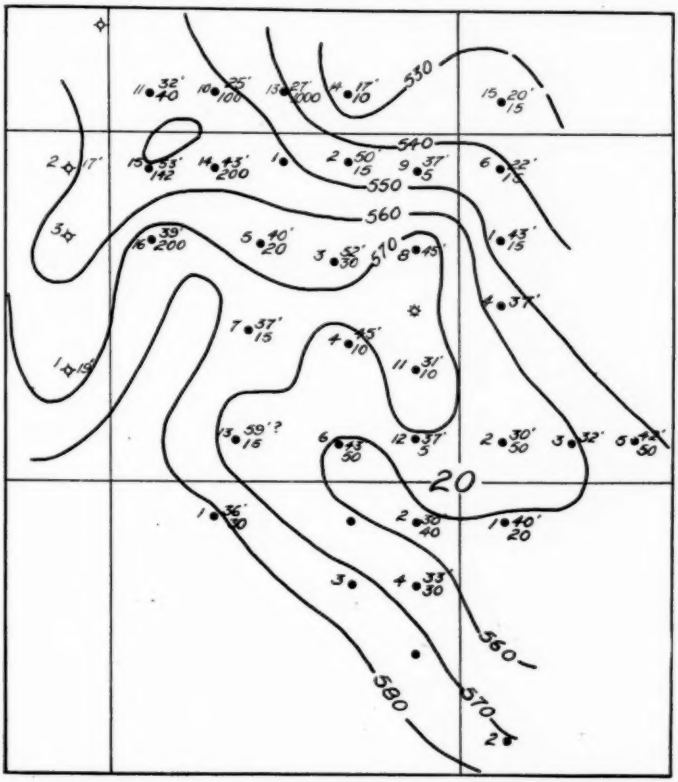

Fig. 1. Small pool in Sec. 20, T. N., R. 9 E., Osage Co., Okla. Contours on top of Peru sand. Figures at right of wells indicate thickness of sand and initial production.

ern Osage and Creek Counties, Oklahoma, which lies between the Pawnee and the "Oswego" limestones. Also, the Peru sand occurs under the "Oswego" in the southern Osage and is frequently confused with the Peru of Oklahoma. The dual use

of this name for two different sands is unfortunate and this lower sand would better be referred to as the Peru of Oklahoma. The Kansas appelation was derived from the town of Peru in the heart of the oil fields where this sand was first encountered while the Oklahoma name was given through a miscorrelation. It might be remarked that the same Nowata shale carries the Whiting and Cleveland sands farther south and they all might be correlated in a long distance manner as one and the same. Production above the "Little" lime is not relevant to the purposes of this paper.

While working out the facts and the conclusions arrived at in this paper a large number of individual pools were studied. It is not possible to reproduce maps of all of them so a number of particular pools that best represent the peculiar conditions encountered have been selected for special description.

In section 20, T. 29 N., R. 9 E., Osage County, Oklahoma, there is a small pool covering approximately three hundred acres. The surface structure across this pool is a straight west to southwest dip and there is no surface folding in the vicinity to which this pool could be related. Figure 1 shows the subsurface structure constructed upon the top of the producing sand. Subsurface contours drawn upon the top of the Lenapah "Little" lime and an upper water sand show minor variations but are essentially the same as to general features. Thus we see that the sand body has a structural form similar to an embayment or lagoon protected by an outer barrier in the form of two structural noses, one extending to the northwest and the other to the southwest. Continuing the comparison with a lagoon we see that the sand body is thickest along the shoreward edge and thins outward to the channel. On the seaward side the sand rapidly plays out. Landward, from the interior edge of the lagoon, the sand rapidly thins out and disappears; a well one half mile east of No. 6 (NW cor. sec. 21) reports no sand whatever. It will be noted that the best production was obtained in a narrow strip in the lee of the northern barrier.

The Barnsdall pool covers about four hundred acres in the northeast quarter of section 35, T. 29 N., R. 11 E., Osage

County, Oklahoma. Surface structure shows no folding of importance. Figure 2 shows the subsurface structure with contours constructed upon the top of the Lenapah "Little" lime which immediately overlies the producing Peru sand. Contours upon the sand and upper water sand are virtually the same. Again we see the embayment feature of the producing

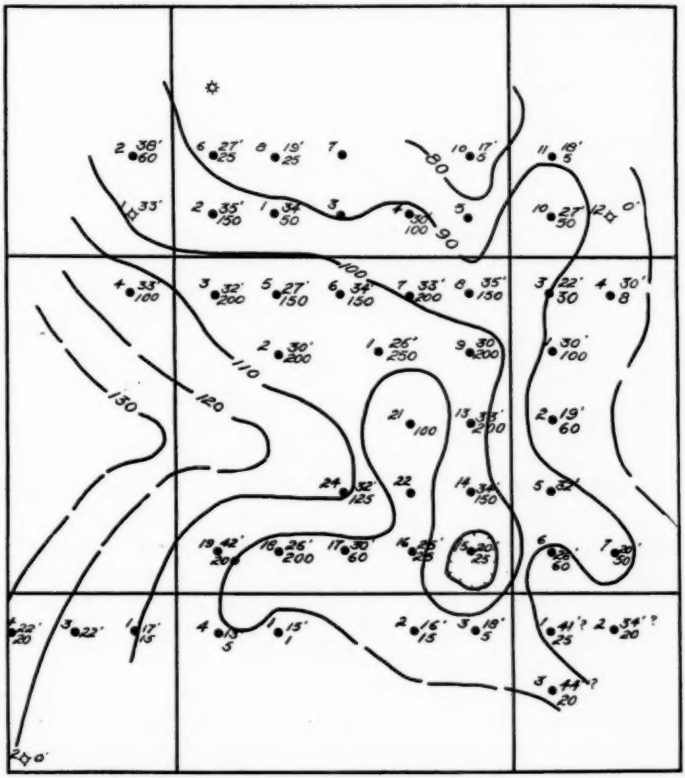

Fig. 2. Barnsdall pool T. 29 N., R. 11 E., Osage Co., Okla. Contours on top of Lenapah Lime.

area, although there is preliminary evidence that the major portion of the pool lies between two local structural "highs. The sand body is thickest in the basin and thins rapidly shore-

ward to the north, south and east. The best production was obtained in a narrow belt roughly parallel to and considerably away from the shoreward facies.

Several miles to the north of the Barnsdall pool there is some scattered development just south of the Kansas line. Figure 3 shows the subsurface structure of this area with contours constructed upon the top of the Lenapah lime. Production seems to be confined to synclinal areas, the sand being cut out higher on the structures and being broken deeper in the troughs. Viewed from a topographic rather than structural standpoint, these two producing areas have the appearance of old river channels, or the deep arms of a bay. Production and sand thickness apparently follow no system. Surface structure in this area generally shows a long nose extending from section 14 westward across section 15, a synclinal area in the southwest of section 22 and another in the northeast of section 21. This surface structure bears a fair resemblance to the subsurface structures in section 22 but very little to that in sections 14 and 15.

In sections 14, 15, 22 and 23, T. 29 N., R. 9 E., Osage County, Oklahoma, and extending northward into Kansas is the Elgin pool. This pool is about one half mile wide at its greatest extent and narrows to several locations at the ends. The pool extends due north and south for over three miles and is clearly a lenticular sand body presumably on the seaward face of a cliff of some size. The sand body is thickest in the center and thins rapidly east and west, cutting out completely from a thickness of 36 feet to nothing in one location. Surface sturcture shows a slight southwest plunging nose across the center of the field.

The Ramsey pool in T. 29 N., R. 12 E., Washington County, Oklahoma, may be briefly cited. Production lies in the synclinal area between a long plunging anticline on the northeast and a smaller fold on the edge of Osage County. The sand is absent up the flanks of the folds.

One more particular case will be referred to before passing to causes. Twps. 28 and 29 N., R. 10 E., constitute the Belmont area. Well records here are very meagre and it was not possible to develop a satisfactory structure map on the

Peru sand. Contoured upon the top of the Mississippi lime the area shows a very large dome extending slightly west of north through section 34 and sections 2 and 3. On the west side of section 35 and the east side of section 34 is a broad synclinal area just east of the dome. Production in the Peru sand is confined to this synclinal area. The highest parts of

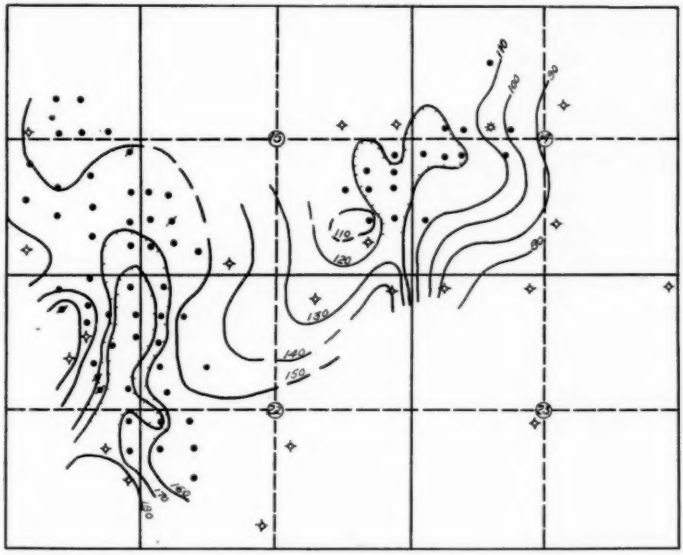

Fig. 3. Part of T. 29 N., 11 E., Osage Co., Okla. Contours on top of Lenapah Lime.

the structure have been productive of gas only from a horizon at the top of the lime. This gas is usually from a gravel or shelly stratum and the only sample which has been observed has the appearance of a conglomerate.

Such conditions as have been outlined above involve a number of causes any of which might be the critical factor. These causes include an eroded and folded Mississippian floor, folding during deposition of the Pennsylvanian, settling of the earlier sediments and a very shallow Pennsylvanian sea with a rapidly oscillating shore line. An outline of the geologic history of this area probably would embrace all of these

causes as contributing factors. At the beginning of the Pennsylvanian there already existed an eroded and folded Mississippian basement, the outstanding feature of which was the Belmont structural uplift. On and around this was a light mantle of fragmentary material, the products of its own breaking down. As the Pennsylvanian sea advanced from the south Belmont stood out for some time at least as an island and was the controlling feature of the currents in these waters on the seaward side. At this time there already existed a topographical trough or basin extending to the north between the ancient land masses of Siouxia and Ozarkja and up which the early Pennsylvanian sea advanced. The sediment brought into this basin by the streams carrying the run off from these old lands were subject to sorting by shore and sea currents and other agencies. The thickness and extent of sand bodies would vary according to distance from the shore, irregularities in the floor, configuration of the shore line, depth of the sea and change in water level. Obviously then there were in this embayment area perfect conditions for the irregular deposition of sands which accumulated in old stream channels, in smaller protected embayments off from the main basin, anywhere in fact except upon top of the small structural folds, already formed in the Mississippian strata and intensified in the Pennsylvanian and which were not covered by waters at that time.

A summary of the conclusions arrived at in the study of many pools is that surface structure in the form of an application of the anticlinal theory is a poor guide to the location of new oil pools in ths area. Most of the production is synclinal and therefore presence of an anticline or dome is not the only factor to be considered. It is believed, however, that production bears a relation to structure in that it occurs on the flanks of local folds or in the synclines between them. Very rarely has it been noted that production occurs in small local depressions without adjacent structural uplifts. Geologists investigating this area would probably arrive at more positive results by studying the early Pennsylvanian paleographic conditions through the medium of well logs than by merely hunting structure.

JOHN L. RICH: I should like to ask whether or not the sand which is productive in the synclines between anticlinal noses is present on the adjacent anticlines. Farther northeast in the shallow fields of Kansas there are several oil pools occurring under conditions similar to those described by MR. HARTLEY, but the productive sand is present in full thickness on the adjacent uplifts, or anticlinal noses. It is, however, either barren or occupied by small amounts of gas.

BURTON HARTLEY. It is variable, being present sometimes, and sometimes not, though the horizon can usually be recognized and traced. The sand is very rarely present in full thickness and is almost always badly broken.

J. ELMER THOMAS: I was much interested in Mr. Hartley's wide correlation of the Peru Sand. With reference to the Peru Sand which he mentioned, I have a suggestion for the consideration of the geologists. I would favor abandoning the term Prue and refer to that sand as the Squirrel. The Prue is, of course, below the Oswego and has no relation to the Peru but it is very often confused by operators and field men because of the simlarity in pronunciation. The Prue sand is the same as the Squirrel and the latter name would seem preferable to prevent confusion with the Peru whose production is more widespread and which is much better known to the oil men.

GEOLOGICAL NOTES

OIL IN IDAHO?

A geologist advocating a search for oil in Idaho is apt to be classed either as a mild lunatic or as a joker with a distorted sense of humor. The mineral wealth of the State is well recognized, but petroleum is commonly omttted from the list of the State's natural treasures. In short the idea that prospecting for oil is unjustifiable has become firmly established that there has been little drilling for oil done in the State outside the Valley of the Snake near Payette, where large but short lived flows of gas were obtained.

It must be admitted by even the most optimistic geologist that about two-fifths of the State cannot, by any stretch of the imagination, be considered possibly oil bearing, since intrusive or metamorphic rocks are known to lie at or close below the surface. However, this leaves about 50,000 square miles, an area larger than the State of Pennsylvania, that cannot so summarily be placed in the non-oil category. Much of this 50,000 square miles is surfaced by lava flows, Tertiary lake beds, and stream deposits which reflect only slightly, or not at all, the structure of the underlying older beds, and wildcatting in these parts of the State will therefore be largely a blindfold proposition, but until extensive wildcatting has been done the region must be admitted to be at least possibly oil-bearing. Furthermore, there are parts of the State, notably in the southeast corner, where neither volcanics nor Tertiary sediments interfere seriously with the search for structure suitable to cause oil accumulations.

The search for oil involves very precise geologic work. Fortunately the stratigraphic work of Schultz, Pardee, Richards and G. R. Mansfield of the United States Geological Survey furnishes a solid foundation upon which to build the more elaborate edifice of minutely detailed stratigraphic and structural work to meet the needs of petroleum geology. Material increase in the knowledge about structural conditions in southeastern Idaho and their possible bearing on petroleum resources has come through the work of Virgil R. D. Kirkham of the Idaho Bureau of Mines and Geology, whose bulletin on "Petroleum possibilities of certain anticlines in southeastern Idaho" was recently issued. This bulletin, which covers parts of Teton and Caribou counties describes a number of pronounced anticlines, but by no means all that are known to be present in southeastern Idaho.

Oil, if present in southeastern Idaho, will probably be in Jurassic, Triassic or Carboniferous formations, although there is also a chance for oil in the Cretaceous. The southeastern part of Idaho is intensely folded and faulted and the fear that alteration of the oil has destroyed chances of success probably has deterred some prospectors from serously considering operations in the State. However, such evidence as is available does not indicate that alteration has progressed so far

as to seriously injure the chances for the persistence of oil. But few analyses of coals from southeastern Idaho have been published, and these analyses are all of Cretaceous coals. The average fixed carbon ratio appears to be about 56, but this may indicate little regarding the extent of alteration in the pre-Cretaceous formations.

In short Idaho contains enormous areas where there is no proof that oil is absent. In parts of the State anticlinal structure is known to exist in beds equivalent in age to strata that yield oil in the adjacent State of Wyoming. This folded region apparently has not been too far altered to prohibit the existence of oil in paying quantities.

K. C. HEALD.

NEW PRODUCING DEPTHS AT EL DORADO, ARKANSAS

Since the publication of two press notices by the United States Geological Survey[1] calling attention to the possibilities of production in the Marlbrook and other formations lower than the present oil-producing Nacatoch sand and suggesting the proximity of other pools, at least two discoveries have been made, renewing interest in the El Dorado field.

In the early part of May, oil and gas were found at a depth of 400 feet below the Nacatoch, and on May 14th, gas production was found in what seems to be the Nacatoch 9 miles north of El Dorado and 100 feet shallower than at El Dorado.

The El Dorado Natural Gas Company's Frazier No. 1 in Section 6, T. 18 S., R. 16 W., made 10 million feet of gas and 2,000 barrels of salt water at 2529 feet. The Magnolia Petroleum Company drilling in Section 5, of the same township, got 50,000 feet of gas at 2518 feet and at 2542 feet considerable salt water.

In E. M. Brown's Goodwin No. 1 in Section 6, T. 16 S., R. 14 W., 14 miles northeast, near Calion, hot salt water and some heavy black oil were found at 2634 feet. This sand may correspond to the 2530-foot El Dorado sand, but if so it dips considerably northeastward. The poorness of the log of this well makes any conclusions very unsatisfactory.

In view of these discoveries a number of wells in the west part of the field are being deepened. This deeper producing horizon has been noted and tested unsuccessfully in about 20 other scattered wells in and near El Dorado field. It lies from 400 to 425 feet below the top of the Nacatoch producing zone, and is generally separated from

[1]U. S. Geological Survey Press Notice: Wildcat wells in South-central Arkansas stop short of deep oil sands, April 22nd. 1922, see this Bulletin, pp. 350-358.

U. S. Geological Survey Press Notice: El Dorado oil field in Arkansas not on an anticline, May 15th, 1922, see this Bulletin, pp. 358-367.

a bed of chalk above by a few feet of gumbo. A *Crenella serica*[2] identified from 2552 feet in the Cooper-Henderson well in Section 19, T. 17 S., R. 15 W., would indicate that this new producing horizon is of Marlbrook age. If this is true then the Marlbrook is about 350 to 400 feet thick and contains thick beds of chalk; 220 feet of chalk having been recorded in the Magnolia Petroleum Company's well, a carefully drilled test already referred to, and 110 feet in the Cooper-Henderson well. Over 100 feet of lime are recorded in the Southern Oil and Land Company's Armstrong No. 12 in Section 31. T. 17 S., R. 15 W., from 2350 to 2450 feet.

If this interpretation is correct then only the small thicknesses of lime, broken with sand and shale, and logged in the deep El Dorado wells as occurring approximately between 2650 to 2750 feet can be assigned to the Annona horizon. If the usual interval of 150 to 200 feet between the bottom of the Annona and the Blossom horizon is allowed, then the sand producing at Haynesville may be expected around 2900 feet in the El Dorado field where the elevation is about 200 feet.

Drilling to a depth of 3,000 feet is, therefore, urged in all wells before abandoning, to test thoroughly the two and possibly three sand horizons below the Nacatoch. No well has ever been drilled in Union County to the Woodbine, or deeper sands, productive in the Caddo, Louisiana, field. The Woodbine at El Dorado may be expected from 3,350 to 3,450 feet.

In Section 8, T. 16 S., R. 15 W., in the northern part of Union County, the discovery of what is presumably the Nacatoch sand structurally 100 feet higher than at El Dorado, makes that territory 9 miles north of the field appear favorable for a new pool. The discovery was made by the Oil Operators' Trust—Murphy No. 1 which blew in unexpectedly with more than 50 million cubic feet of dry gas from a depth of 2024 feet. As no wells have been drilled within less than 4 miles of the Murphy No. 1, the area to be tested is rather extensive. The discovery well is blowing wild and burning intermittently.

V. P. TEAS.

Shreveport, La.
June 9th, 1922.

POSSIBLE SUB-SEA ANTICLINES, GULF OF PARIA. TRINIDAD-VENEZUELA

The basis for the writer's opinion that there are several well developed sub-sea anticlines under the Gulf of Paria, Trinidad, B. W. I. is to be found on the British Admiralty chart No. 483-A, "West Indies,

[2]U. S. Geological Survey Press Notice. Oil from the Nacatoch sand, El Dorado, Arkansas, February 7th, 1922.

Trinidad Island and Gulf of Paria" by Commander W. Chimmo, R. N., H. M. Surveying Ship "Gannett," made in 1866 and 1868.

Trinidad Island contains numerous well developed anticlines. Some of these are known to be productive of considerable quantities of petroleum. In the vicinity of the "Oropouche Lagoon," longitude 61° 30′ west; latitude 10° 11′ north, there are no less than nine distinct structural uplifts. The strike of the major axes of these folds varies from due east and west, to south 70° west. The anticlines are generally asymmetrical, the south flank having the lesser angle of dip.

The Admiralty map mentioned indicates sixteen definite strike-ridges existing under the Gulf of Paria. With the exception of four of these sub-sea elevations, the strike is approximately the same as that of the anticlines to be observed on the Island of Trinidad, B. W. I. and the northeastern mainland of Venezuela, S. A.

It is probable that the extensive seeps of petroleum situated about the mouth of the Rio Perdenales, Venezuela, in latitude 10° 02′ north; longitude 62°. 12′ west, are located on a sub-sea fold extending from the Island of Trinidad into Venezuela on the west. The rocks "Soldado," "Pelican," "East," and "Black" exposed above the waters of the Gulf of Paria, are visible evidences of these sub-sea anticlinal extensions in the vicinity of the mouth of the Rio Perdenales. The strike of the uplift is approximately east and west on its submerged eastern half and south 65° west on its western or Venezuelan end.

The elevation of the top of the several strike-ridges above the floor of the Gulf of Paria varies from 30 to 120 feet. The length of the sub-sea ridges varies from fourteen to twenty-one miles. The average width ranges from two to seven miles, the lesser figure denoting the width generally common to the elevatons.

LEWIS C. CHAPMAN.

A CHANCE OF MORE OIL IN SOUTHWESTERN TEXAS

The U. S. Geological Survey on July 24th issued a Press Notice with the above title describing anticlinal folding between Del Rio and Sycamore Creek, in Val Verde County. Texas. The structure is an anticline with its axis extending west by north, crossing Sycamore Creek about 2 miles south of the Southern Pacific Railway near Johnstone siding, and extendng across San Felipe Creek 3 or 4 miles north of Del Rio. The abnormal eastward extension of the Buda limestone, almost surrounded by the Eagle Ford formation, afforded the clue to the recognition of the structure. This evidence was checked against the War Department topographic map (not published) and the formation boundaries plotted on cross sections made from that map show a reversal of dip of about 100 feet within a distance of about 4 miles north of Johnstone. Since the notice was written the Reclamation well in sec. 491, Bl. 4, 6 miles north of Del Rio, found asphalt in the basal Cretaceous sand at a depth of about 2,500 feet. Seepage oil now produced

at San Felipe Springs near Del Rio issues from a fault zone in the Georgetown limestone. In this connection it is interesting to note that in 1907, J. A. Udden[1] mentoned the reported occurrence of oil in "some well Johnstone Siding."

[1]Report on a geological survey of the lands belonging to the New York and Texas Land Company, Ltd., in the Upper Rio Grande embayment in Texas. Augustana Library Publications No. 6, Rock Island, Ill., p. 66, 1907.

L. W. STEPHENSON.

ORDOVICIAN OIL AT HEALDTON

A third well in the Healdton oil field has been completed in the Ordovician. It is the Gilmer Oil Co. Hernstadt No. 5, NE cor.. NW¼, SE¼, sec. 4, T. 4 S., R. 3 W., depth 2,100-2,200 feet. The oil is 42 gravity and is similar to that found several years ago, but the depth is shallower.

SIDNEY POWERS

DISCUSSION

Wildcat Wells in South-Central Arkansas Stop Short of Deep Oil Sands.
U. S. G. S. Press Notice, April 22nd, 1921, 8 pages and
correlated graphic logs, This Bulletin, Vol. 6, p. 350.

This press notice of the U. S. Geological Survey is a warning that more oil and gas production in South-Central Arkansas is not being discovered because of too shallow drilling and careless rotary methods.

These two causes of unnumbered failures have long been recognized by operators and geologists, who have often been helpless before the gods of Expense and Speed. Deep holes are costly and frequently dry even if scientific, and core barrelling takes time and prevents the driller from making hole. Furthermore, new pools have been discovered in such rapid succession in North Louisiana and South Arkansas, that one district has not begun to be thoroughly developed before a new one demanded the operators' attention.

In the last year, however, new production from greater depths, both actual, structural, and stratigraphic, has shown the importance of going deeper. Production was found at Haynesville, Louisiana, in the Blossom sand deeper than before known,—700 feet both structurally and actually lower than the Blossom at Homer. Likewise, it was found at El Dorado, Arkansas, in the Nacatoch, 700 feet lower than the same sand at Homer. Furthermore, a new producing horizon was found at Pine Island in the Caddo, Louisiana, field for the first time in the Glenrose formation of the Trinity series at a depth of 2,900 feet below the surface.

Phenomenal production from these unprecedented depths in this territory gives weight to the advice of the Survey that, "Cores should be cut from all beds penetrated that yield showings and particularly from a sand in the Nacatoch, Marlbrook, Brownstown, Blossom, Eagle Ford, Woodbine, and Trinity formations, whether or not oil showings are observed in the sludge."

A large part of the paper is taken up with a description of the formations encountered by drillers in Union County, Arkansas. This is the results of a detailed study of many well records by W. W. Rubey, and together with a typical log of the El Dorado field forms a valuable guide for wildcatters.

The general structure of the region, including regional southeast dip and thickening of beds toward the center of the Mississippi Embayment, is graphically shown by cross section correlation of eight well logs from Howard County to Union County. This indicates a slight flattening or terracing of dip near Stephens and El Dorado.

A few points brought out in the paper whose truth may not be generally realized are:

1. "The principal oil sands of the Caddo and De Soto-Red River

districts in Louisiana (which are commonly but erroneously called the Woodbine sand) are probably of Eagle Ford age."

2. The Eagle Ford formation contains red shale which may be used for correlation purposes.

3. The Annona tongue of the Austin chalk may be absent in Southern Arkansas, although it probably is not always recognized because of its shaly nature.

4. The Woodbine sand, so far as known, has not been reached in Union County. Quoting L. W. Stephenson, the paper suggests that Woodbine may be represented by an unconformity.

5. The Trinity formation is probably 4,000 to 5,000 feet below the surface in this region.

It is correctly stated that many wells in South-Central Arkansas stop short of the Nacatoch and the Blossom sands. It is likewise stated that in other fields several sands below the Nacatoch have been more productive than the Nacatoch, and in fact the Nacatoch has been barren in some fields.

It is stated, however, that the sand in South Arkansas corresponding to the producing Eagle Ford (erroneously called Woodbine) in De Soto-Red River, probably lies 1,300 to 1,400 feet below the top of the Nacatoch, or at a depth of 3,400 to 3,500 feet below the surface. In April, when the Press Notice was written, few if any wells in South Arkansas had been drilled that depth, and this fact apparently furnished part of the reason for the title, "Wildcat wells in South-Central Arkansas Stop Short of Deep Oil Sands," but the necessity of drilling that deep is not at all clear.

If we agree, as some geologists do, that the Woodbine is absent at El Dorado and in the De Soto-Red River field, and that production in the latter place comes from the Eagle Ford, and if we agree, as a number of geologists who have studied the El Dorado field do not, that the Cooper-Henderson deep test at El Dorado is in Eagle Ford at 3,005 feet, then we should agree that the wells, at least those wells used in the correlation table of the Press Notice, went deep enough to reach the producing sand of the Eagle Ford, if there were such, and that it is unnnecessary to go 1,300 or 1,400 feet below the top of the Nacatoch in Union County, for the following reasons:

1. In De Soto-Red River, the producing horizon is less than 100 feet below the first red shales and clays of the Eagle Ford.

2. The wells used in the correlation tables show depths several hundred feet below the red shale.

According to this argument then, it appears that the title of the Press Notice is appropriate for wells shallower than the Nacatoch and Blossom, but misleading as applied to wells in red shales of the Eagle Ford,—unless the operator wants to take the chance of drilling to the Trinity which is estimated by the Survey "to lie 4,000 to 5,000 feet below the surface."

J. P. D. HULL.

El Dorado Oil Field in Arkansas Not on an Anticline

U. S. G. S. Press Notice, May 15th, 1922, 6 pages and map, This Bulletin, Vol. 6, p. 358.

This press notice is the result of field studies of the geologic structure made in the summer of 1921 by W. W. Rubey, L. G. Mosburg, and H. W. Hoots, and office studies by K. C. Heald and W. W. Rubey.

The notice states, "The primary purpose of these studies was to learn the conditions under which oil is most likely to occur in southern Arkansas." It deals with the discovery and development, structure, source of oil and formation of pool, oil and gas above "pay" sand, possible extensions, suggestions for finding similar fields, description of producing bed, methods of constructing map, and character of oil.

The principal facts brought out by this study are the lack of pronounced anticlinal structure and the close association of gas, oil, and salt water in the same producing bed.

The striking feature of the geologic structure map is the portrayal of a number of small faults approximately parallel in a northeast direction. A quotation from the paper indicates their significance.

"The direction and arrangement of the faults, and the shapes of the folds that accompany some of them, probably indicate the presence of a large fault or zone of faulting in the beds deep below the Nacatoch Sand, trending about N 15° W. The structure shown by the oil sand there must have been produced by lateral movement along this fault, the strata east of it moving northward relative to the strata west of it."

The construction of this sentence is not clear, but apparently the authors accept the theory of A. E. Fath that a series of parallel faults are the result of torsional movement along a deeper fault zone with a trend at right angles to the shallower faults. Further, the authors evidently do not accept the evidence of faulting shown in the surface outcrops in the cen. SE¼ sec. 32 where a fault trends northwest, apparently bounding production on that side. Other geologists have failed to find subsurface faults in the field.

The authors believe the source of the oil is the Marlbrook marl about 400 feet below the producing Nacatoch sand. In fact, since the publication of the press notice, a few wells drilled 400 feet below the Nacatoch have found a little oil, several millon cubic feet of gas, and much salt water. They also believe production from deeper sands cannot be counted on because El Dorado has neither pronounced regional uplift nor strong anticlinal folding, which are favorable features in the other deep-producing fields of southern Arkansas and northern Louisiana. It may be mentioned, however, as an encouraging comparison, that at Haynesville, Louisiana, production comes from the Blossom sand 2,800 feet deep, and 800 feet below the Nacatoch on a rellatively low fold whose closure is only 60 feet. At El Dorado, there are probably closures of 30 feet and the total producing structural relief is as much as 70 feet.

Several suggestions brought out in the paper are (1) the importance of stopping the drill at the very top of the producing bed, since, "so far as salt water is concerned this field may be said to be all 'edge', and each well is a problem in itself." (2) the possibility of production in both shallower and deeper sands, and (3) the probability of nearby fields of similar character.

Two sentences that stand out from others in the reader's mind are here mentioned: (1) "The great number of test wells that have been drilled in southern Arkansas without finding oil in large quantity except in the El Dorado field show either that the oil pools in this region do not bear the same relations to anticlinal structure that they commonly bear elsewhere in the Mid-Continent Oil fields, or that geologists have not learned how to locate the anticlines in this field by studying the surface conditions." This statement, made with the apparent premise that all southern Arkansas test wells have been located by geologists and drilled with geological precaution, is very flattering to stock concerns, contract drillers, and wiggle-stick artists. (2) "The records of wells drilled with rotary tools are notoriously poor and afford very unreliable correlations." This is the truth, but not all of it. There are drillers and then again there are drillers. To cite Haynesville once more—geology found it and drilling almost lost it.

J. P. D. HULL.

Shreveport, La., July 5, 1922.

REVIEWS AND NEW PUBLICATIONS

Unproved Areas. By LAWRENCE VANDER LECK, California State Mining Bureau, Bull. 89, 1921.

California State Mining Bureau, Bull. 89, 1921

This recent publication by the California State Mining Bureau has supplied a long-desired need for a summary statement of the petroleum possibilities of the State. It is sincerely hoped that Mr. Vander Leck's clear map and pointed statements as to the situations existing in all parts of California will have an effect on diminishing the large sums of money spent on drilling in areas where obviously there is no chance of obtaining oil. The book should be consulted by every prospective investor before placing his money with a "wildcat" company. As Mr. Fletcher Hamiliton, State Mineralogist, has so concisely stated in his letter of transmittal to the Governor of California. "The increasing demand for petroleum and its products, and the inability of production to keep pace with requirements, for several. years, have resulted in widespread prospecting throughout the world for possible new oil fields. In California, 'wildcat' wells are being drilled in many localities, some of them in places where even a cursory inspection of the geology would tell of the futility of looking for oil. For this reason, the report herein aims cc to furnish information as to the unfavorable as well as to the favorable areas for development of additional petroleum resources in California."

After a "General summary of conclusions" which is well-placed at the beginning of the book, Chapter 1 discusses the "General theory of the origin and accumulation of oil in California." In trying to make this comprehensive subject as concise as possible, the author has left out many essential points. His definition of the organic theory is extremely vague. Diatoms and forams are taken for granted as the source for the oil in California—diatoms for the reason that the "California oil shale shows that they (samples) vary from 65 per cent to 85 per cent silica." It is extremely doubtful whether forams could act as a source for oil[1]. Three theories are given for the migration and accumulation of oil, namely, (1) anticlinal, (2) moving waters, and (3) the diastrophic theory of Marcel Daley. These are very briefly explained with the conclusion that "It is very probable that all of the above theories contain some element of truth, and the forces that contributed to the migration may possibly be a combination of all these forces." This part could be greatly improved by the addition of references to the literature on the various theories. A summary statement is given of the structures in which oil occurs in California, all of which bear out the rather positive assumption that "oil travels later-

[1]Personal communication from Dr. Albert Mann of the Smithsonian Institution.

ally and vertically—never downward....." The discussion of the less theoretical part on "Reservoirs" presents a good idea of the underground storage condition in California, though the statement that "In general, fine-grained sands contain light oil, while coarse sands contain the heavy viscous oil" may be questioned. The part on "Saturation and recovery" is briefly handled, but adequately for this type of book. It mainly concerns the value of the gas associated with the oil. The different classes of "Surface indications of oil" found in California are given and their importance in relation to the occurrence of oil is pointed out.

Chapter 2 describes the oil-bearing formations of California. The State is divided into five provinces, and the general geology and structure of each province is briefly discussed. The oil-bearing formations, of California ranging in age from the Cretaceous to upper Pliocene, are dealt with in more detail. In the introductory parapraph the statement that "all known occurrences of oil in California are found in close formation with beds of organic shale" is misleading. Although some of the organic shales closely associated with the occurrence of oil in California contain diatoms and may, in places, be composed almost entirely of them, still a very large part of the oil shales contain very few, if any diatoms. For example, the oil derived from the Eocene in Ventura County is certainly not associated with diatomaceous shales. Short descriptions of the California oil-bearing formations are difficult to give when it is considered that the lithology varies so greatly from place to place. As a whole, Mr. Vander Leck has handled the subject well, listing the principle localities where the formations occur, and stating the mode of occurrence of the oil in them, the kind of oil, and the commercial possibilities of the formation. As regards nomenclature, always a vexatious task in California stratigraphy, he has, in general, followed that used by Dr. B. L. Clark of the University of California.

The remainder of the book is taken up with the detailed discussion of the prospects for oil in California. For this purpose, the State has been divided into eleven districts with a chapter devoted to each district. The geology of the areas is briefly summarized and where certain districts are oil bearing or offer possibilities for oil, details of the geology are given either from first hand information of the author, or from quotations and abstracts of other geologists' work, supplemented by the author's own observations. Where the geology has been taken from old Government and State reports, it is not always accurate in the light of our present knowledge. A great deal of valuable data is given on the results of the wildcat wells of the districts, information about which is sometimes difficult to get years after the wells have been drilled. A colored map has been included showing the proven, possible, improbable, and impossible areas of the State. Though references are freely given, a welcome addition would have been a more

complete bibliography of the literature relating to the petroleum geology and industry of California. Numerous grammatical errors, involved and abstruse sentences, and misspelled words show that the book could have been markedly improved by editing.

As a whole, the author's conclusions are reliable, the data on the fields useful, concise, and well-arranged, so that the book should be of considerable value not only to the ordinary investor, but to anyone interested in the petroleum industry of California.

W. S. W. KEW.

Appraisal of Oil Production By J. H. HIGHSMITH, published by the author, Lawrenceville, Ill., 1922. pp. 132, price $5.00.

The chief contribution of this book is a series of tables for use in determining monthly depletion rates based on past performance of oil-producing properties, and for estimates of future yields.

The book opens with a two-page introduction on the subject of oil appraisal by R. S. Blatchley, in which he compares three methods of estimating oil reserves, (1) production curve method, (2) porosity method, (3) direct percentage method.

The reviewer wonders if Mr. Blatchley is as prejudiced against the production curve method as his comments imply. This method is graphic and hence may appear less accurate than the direct percentage method, but in the hands of anyone with some experience and appreciation of oil production, it gives good results and obviates one inaccuracy of the latter method, the assumption of a fixed rate of decline. Certainly it is no more, but is rather less arbitrary than the direct percentage method which assumes a fixed rate of decline, such as may be approached by a property in old age but which, so far as the reviewer knows, is never actually reached. The older the production the less rapidly in general, does the decline rate change. In the case of old properties tables should give reasonably accurate results, but consistently should run low.

Mr. Highsmith takes up the problem of estimating future reserves, and includes examples with solutions which are intended to illustrate the use and scope of the tables in the book. Each table consists of four columns, (1) a time column of one to twelve months followed by year totals through ten years, (2) a given monthly depletion rate applied each month for the same time interval as that in coulmn one, (3) the residual or "depletion point" as it is called by the author for each of the time intervals given in column one, and (4) a factor which represents the cumulative or total production through each of the time intervals. The tables are based on a monthly decline rate, which is assumed to remain constant in the future. The range of these rates is from ¼ per cent per month up to 3 per cent by 1/16 per cent intervals, 3 per cent to 5 per cent by ⅛ per cent intervals, and 5 per cent to 10 per cent by ¼ per cent intervals.

While it is not possible precisely to estimate future oil reserves, aid to accuracy and speed in such work are valuable, though greater convenience and ease of use do not necessarily mean greater accuracy.

Mr. Highsmith explains the use of the tables in a simple and concise manner. The last paragraph on page 9, to the effect that "it is evident in most cases that the later life of a well or property affords a safer basis for calculation by any method," is worthy of emphasis, and he might have added, "no method yet devised is fool-proof."

One point to which attention should be directed is the fact that these tables are intended for use in the study of individual wells or leases where no drilling has taken place during the period for which the average rate of decline is determined, nor is any allowed for in the future. If these limitation are not adhered to, the results attained lose accuracy.

Mr. Highsmith has chosen examples which show in an admirable manner the convenience and utility of such tables. His solutions are clearly given, and should be followed by anyone without difficulty. A statement of problems which are presented will indicate some of the occasions where the booklet can be of considerable assistance.

Problem 1. Find the monthly production and total yield, at the end of three years, of a property producing 3,000 bbls. monthly on which the monthly decline rate is shown to be 1½%.

Problem 2. Same condition as No. 1. Time 3 years, 7 months.

Problem 3. What monthly decline rate is indicated by a decline in the monthly production from 3,000 bbls. to 1,285 bbls. in 4 years?

Problem 4. What monthly decline rate is indicated for a property with a basic monthly production of 9,875 bbls., which showing a steady decline, yields 275,250 bbls. in 3 years?

Problem 5. What monthly rate is indicated by a drop in the monthly yield from 3,875 bbls. to 2,925 bbls. in 2 years and 8 months?

Problem 6. What monthly decline rate is indicated for a property producing 3,275 bbls. monthly which, showing a steady decline, yields 76,425 bbls. in 3 years and 6 months?

Problem 7. A property with an average monthly production of 4,875 bbls. on January 1, 1918, showing a steady decline yielded to January 1, 1921, a total of 141,785 bbls. The monthly operating cost being $1,575.00, place a valuation on the production on a 7% interest paying basis only, with market price of oil running throughout at $1.75 per bbl.

Problem 8. A property showing a daily average production of 125 bbls. and a depletion rate of ¾% monthly is purchased for $1,600.00 per bbl. The monthly operating expense bing $1,500.00, in what time will the property pay out, allowing 7% interest, with the price of oil running throughout at $1.75 per bbl.?

The reviewer cannot agree with the author in his solutions for the problems 7 and 8.

The author calls attention to the fact that his "solution does not take into account the reduction of the interest charges by the amount of interest earned after the first year on returns from the sale of production." A serious error which is involved in the solution is the method used for determining the net value of oil per barrel for each year's run. This has been determined on the basis of the first year's production, although the monthly operating cost is essentially a constant, the monthly yield is a declining amount, and the cost per bbl. is therefore a variable, increasing towards the end of production. Such a calculation shows a net value of

$1.25 per bbl. for the first year's production, and this net value is applied to all subsequent production, obviously an oversight on the author's part.

The author's results for this problem are as follows: During a period of 8 years and 9 months the property should yield 188,591 bbls. which at 7% interest should have a present value of $146,194.57, and the value per bbl. on the basis of the January 1921 production (105) would be $1,392.00. The reviewer has recomputed this problem on the basis that an investor would expect 10% interest on his investment for the life of profitable production, that the proceeds for each year's oil sales might be considered as coming in during the middle of that year, and that the replacement or amortizing fund should build up at 4% compound interest. On such a basis, this property would have a profitable life of 6 years, during which time the total yield would be about 152,220 bbls. The net receipts for each year's production would be as follows: $42,768.25, $34,532.75, $27,396.25, $21,213.50, $15,756.75, and $11,214.00. These amounts capitalized as above outlined would have a present value of $104.550.84, and the value per bbl., based on the January 1921 production would be about $1,000.00. As such a method of capitalizing future income is commonly applied to the valuation of a mining property, the reviewer considers it as applicable here.

Mr. Highsmith in his solution for problem 8, finds that at the end of the fifth year the property will have overpaid by $2,955.00, and should have produced 180,366 bbls. Here again the reviewer starts out on a different premise. He considers that 10% interest is the minimum an investor should expect on such an investment, and allows the amortizing fund to compound at 4% interest. On such a basis, this property is worth only $184,454.00 (or about $1,475.00 per bbl.) and would take 8 years to pay out. The yield during this period would total about 253,435 bbls. In this case the amounts which are capitalized are as follows: $56,452.00, $50,013.75, $44,146.00, $38,777.28, $33,879.94, $29,392.13, $25,298.50, and $21,558.46.

With the limitations in mind to which attention has already been directed, the reviewer can cordially commend this booklet to the attention of all those who are concerned with the valuation of productive oil properties, and he believes that it is a real addition to our literature on petroleum problems.

JAMES H. HANCE.

Oil Finding, By E. H. CUNNINGHAM CRAIG, published by Edward Arnold. London, 1920.

The second edition of this valuable book is an enlargement and amplification of the first that was published about 1912. The work consists of some three hundred odd pages and deals with the theories of the origin and occurrence of petroleum. It covers in a thorough way the field of petroleum geology. Also, there are chapters on related subjects as, "Petroleum Prospects in Britain" and "Field and Office Methods."

The volume is a contribution to science, and treats the subject of petroleum geology in perhaps the most orderly, concise, and thorough manner of any book that has, as yet, been published. In addition, it is a most welcome departure from the ancient and established custom of quoting Peckam, Newberry, and Orton as oracles, and, after this preliminary step, proceeding to compile a digest of what everybody else believes except one's self. A man, widely traveled, and keenly observant, Craig has given the profession the benefit of his studies undi-

luted by numerous quotations from the writings of others. The work is distinctly that of a field man and not of a librarian. Even though many of us may differ with him in some of his conclusions, the reviewer believes, his book stands as the best published contribution of the statement of the science of petroleum geology as it is known today.

Chapter I, devoted to "The Origin of Petroleum" covers forty-three pages. Six pages are given to examples disproving the volcanic theory. These examples are very interesting especially the description of cracked oils that occur in the dolerite dikes of South Africa. The next twenty-two pages are devoted to statements of the theories of animal origin and an attempt to disprove them. The theory of vegetable origin is then considered for seventeen pages and the chapter terminated with a discussion of the untenability of the suggestion that petroleum could have been formed from marine vegetation. The whole chapter is really an attempt to prove the origin of oil from terrestrial vegetation accumulated under deltaic conditions.

Chapter II, entitled "Process of Formation" refers entirely to the supposititious formation of petroleum from terrestrial vegetation. Various suggestions are offered and field examples quoted in support of the argument which is carried on under the sub-titles of "Pressure," "Temperature," "Salt and Brine."

Chapter III is headed "The Migration, Filtration, and Subterranean Storage of Petroleum." The first few pages are taken up with a discussion of petroleum as a colloidal solution. Then statements are made against the acceptance of the idea of the migration of oil over wide areas as a general phenomenon. The author considers migration a special or local condition. The various subjects of "Hydrostatic Pressure," "Gas Pressure," "Surface Tension," "Filtration," "Subterranean Storage," "Contour of Grain," and "Porosity" are treated under these sub-titles. Filtration effects are treated at considerable length and seem to be given unusual prominence. Under surface tension a "crack" is taken at our prevalent use of the term capillarity, and two quotations are given. The quoted discussions of capillirity are so badly jumbled and confused that they have little meaning. The author gives them as verbatim from what he alleges are, "recently published books upon petroleum ..... hailing from the United States." It is then explained in a kindly manner that capillary attraction is an obsolete term and that the correct and proper phraseology is surface tension.

Chapter IV is entitled "Lateral Variation." The change in character of sediments that compose a horizon or are laid down during any period of deposition are discussed at length with examples taken mainly from Trinidad and Burma.

Chapter V is devoted to a discussion of geological structures and numerous examples of the working out of such structures given for various countries.

Chapter VI is on "Indications of Petroleum." These are listed as: (a) seepages of oil, (b) asphalt deposits, (c) evolution of gas from

strata, and (e) veins of manjak or ozokerite. Evolution of hydrogen and crystals of sulphur are appended. Attention is called to the fact that petroleum seepages nearly always represent either oxidized of filtered oils. There is also a rather full description of the pitch lake in Trinidad, and numerous localities are listed where this type of manifestation occurs. The chapter is closed with a tabulated list of what the author considers favorable and unfavorable indications.

gas-pools, mud-volcanoes, or dry ground, (d) outcrops of bituminous

Chapter VII has the title, "Natural Gas or Gaseous Petroleum." The term "gaseous petroleum" coined by Sir Boverton Redwood is used by the author in preference to what he calls the American misnomer of "natural gas." The chapter treats fully the geological occurence of natural gas at a number of localities.

Chapter VIII on oil-shales and torbanites devotes the first half to a theoretical discussion of the origin of Scottish oil-shale while the latter part carries out the same idea for torbanites, that is, cannel coal.

Chapter IX is on Stratigraphy. This arrangement may seem peculiar to those accustomed to see the subject treated at the beginning of most books or reports. One interesting subject in the chapter is a description of the method used by the Burman Oil Co's geological staff in zoning their fossils. The author mentions that most satisfactory results were obtained in separating the series into mappable units without any of the members being trained paleontologists.

Chapter X on the location of wells discusses the various methods used in following a "hunch," and the possibilities of electrical divining rods. The author seems to give more credence, than most of us to the possibility of an electrical instrument that will measure relative conductivities of oil or water impregnated sub-surface strata. The major part of the chapter deals with the location of wells on asymmetrical anticlines. Locations on other types of structure are considered in less detail.

Chapter XI is on the "Petroleum Prospects in Britain." The author summarizes the prospects of that country and concludes while structure, stratigraphy, and indications of petroleum are favorable that any such deposits have been dissipated, that possibility of commercial oil is very doubtful, and that was justified only as a war measure.

Chapter XII which is on "Field Work (for beginners)" contains many useful hints from the author's wide and varied experience. Most of the methods cited are especially applicable to unknown country as is found in the tropics. The widely used plane-table, that is more or less the basis of all American practice, is not touched. With some of the methods recommended and the conclusions drawn probably many American geologists will take issue. A case in point where the reviewer thinks the author decidedly in error is with the sketching board. He quite agrees that the old cavalry sketching board is of little use, but calls attention to the modified forms that are now manufactured which give excellent results. Also, horseback traversing is not to be despised

except for the most detailed work and then a plane-table and alidade is recommended.

Chapter XIII which closes the book is given to "Indoor Work" likewise "for beginners." This chapter contains many valuable hints, but the American geologist will probably find the author's procedure somewhat different from his own.

K. D. WHITE.

MANUSCRIPT BIBLIOGRAPHIES

The National Research Council has recently issued a "List of manuscript bibliographies in geology and geography." Under the heading Petroleum there are five entries. G. B. Richardson, U. S. Geological Survey, has several thousand entries of publications since 1900. E. W. Shaw has 1,000 entries, 90% complete, on Latin American petroleum. The Bureau of Mines issues monthly manuscript bibliographies of petroleum in mimeographed form. E. DeGolyer has 9,000 to 10,000 entries in petroleum and natural gas, 80% complete. Roswell Johnson has 7,000 entries of the same nature. These bibliographies may be consulted by all interested.

SIDNEY POWERS

NEW PUBLICATIONS

The branch office of the U. S. Bureau of Mines at 508 Consolidated Royalty Bldg. Casper, Wyoming, has issued the following publications:

Report of Operations of the Rocky Mountain Petroleum Association; May 16, 1919 to May 15, 1921, by F. B. Tough, et al. The cost is $1.00.

Circular No. 5 (2 Mimeographed pages) deals with the computation of government royalty.

THE ASSOCIATION ROUND TABLE

COMMITTEE WORK

Many activities of organizations whose membership is geographically widely scattered, are necessarily performed through the instrumentality of committees. It is commonly the fate of these committees to struggle along unaided, with the work allotted to them, until such time as they are to submit their report and disband. It is unfortunately true that the average member of most scientific societies usually totally ignores the work of committees while it is in progress, and then exercises the utmost freedom in criticising the report when submitted. Attention is once more called to the work of an important committee of the Association, in the hope that members will be aroused out of their lethargy to offer support and suggestions.

The Constitutional Committee has before it the task of recommending to the Association a new method of electing officers. For some time there has been a feeling that the present method of conduction elections is not entirely satisfactory. It has been contended that a larger number of nominations should be submitted for the several elective offices and there has been criticism of the fact that members unable to attend business meetings were denied a vote in the elections. It has been poitned out that on several occasions officers were elected by a majority vote of those in attendance at the meetings, though the entire vote cast represented scarcely more than one-quarter of the total membership.

If absentee voting is to be provided for, the balloting must be conducted through the mail and if announcement is to be made at the annual meeting of the selection of officers for the ensuing year, some means must be found for making nominations well in advance of the meeting. There is a marked indisposition among members to reduce the election of officers to a sterotyped process. Those who support the present system do so largely because they believe the "convention system" adds an active interest to the meetings and encourages attendance. Though the system has worked satisfactorily in the past, it will scarcely be denied that it makes possible electioneering and pledging of votes, which may serve to arouse personal animosity and thus interfere with the successful functioning of the Association as a scientific body.

It will be seen that there are several difficult angles to this problem. Judging from the active discussion of this topic at meetings, the Constitution Committee was justified in expecting hearty assistance from the membership, but despite the fact that the committee has been in existence for over half the current year, only two or three suggestions of a constructive nature have thus far been received. It is hoped that anyone with suggestions which are likely to prove helpful in formulating a workable election plan will not delay longer in communicating them to the Chairman, Chester W. Washburne, 2 Rector Street, New

York, or to other members of the committee, F. G. Clapp, W. E. Pratt, and Jas. H. Gardner.

W. E. WRATHER.

MEMBERSHIP APPLICATIONS

During past years it has been the duty of the Executive Committee to pass upon the qualifications of applicants for membership in the Association. It is now the custom for some member of the Committee, usually the Secretary, to supplement the data contained in the original applications, with information from other sources, if such data are incomplete or inadequate; and upon the unanimous approval by members of the committee, the applicant is declared elected.

During the past two years there has been a great increase in membership, and many applications have been received from widely scattered localities. It has been increasingly difficult for the Executive Committee to secure adequate information upon which to elect members, since it is frequently desirable to know more about the qualifications of applicants than is supplied in the usual manner. It was accordingly thought advisable to publish in the Bulletin a list of pending applications, together with the names of the sponsors, and defer election until after a sufficient lapse of time for members to communicate to the Secretary any data which might have a bearing on the final action of the Committee. The standards of membership can best be maintained if members will co-operate with the Executive Committee by promptly checking over the lists appearing in the Bulletin and furnishing pertinent data to the Secretary.

W. E. WRATHER.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the names of each applicant.)

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E. F. Davis

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Paul Ruedemann
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Robert B. Campbell, Shreveport, La.
Eugene Holman
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Robert R. Osborne, Pittsburgh, Pa.
L. G. Huntley
Paul Ruedemann
R. E. Somers

Shamus O'Brien, Florence, Kansas.
R. S. Knappen
A. C. Gester
R. C. Moore
Sam Kornfeld, Tulsa, Okla.
James H. Garden
W. B. Wilson
Harry H. Nowlan

AT HOME AND ABROAD

H. A. NOBLE, of Tampico, has visited the Laredo, Texas, district.

HARVE LOOMIS is representing N. L. Amster, with headquarters in Tulsa.

The Bend arch in Texas was first recognized in 1915 by Dr. E. T. DUMBLE in the Trans. Amer. Inst. Min. Engrs., Vol. 52, p. 250, where he refers to it as the Lampasas geanticlinal and states that the uplift occurred after the deposition of the Bend series and extended from the old Paleozoic land area of the Llano region toward Red River.

HENRY HOWE has been appointed professor of geology at Louisiana State University.

EUGENE HOLMAN, of Shreveport, spent his vacation in California.

E. T. DUMBLE, of Houston, has purchased an estate at Tunstall, Virginia, near Richmond, and will spend the major portion of his time there and in New York.

W. H. FOSTER, of Tulsa, has been in Mexico City.

J. Q. MYERS, of Tulsa, spent September in Wyoming and Montana.

C. R. THOMAS and W. C. KINKEL, of Tulsa, took a trip through Wyoming and Montana in September.

W. L. WALKER is now living on a ranch near Bakersfield, California.

HARRY BROWN and W. L. LONGMIRE, of the Pierce Oil Corp., will have headquarters in Tulsa.

K. C. HEALD, of the U. S. Geological Survey, has been making a tour of the West. Recently he has been making a survey of the Ingomar dome in Montana.

DONALD MACDONALD has been presented by the United States with a testimonial for his work on the Canal Zone.

RAYMOND LEIBENSPERGER, of the Transcontinental Oil Co., of Mexico, published a paper on the history of oil development in Mexico in the Lamp for October.

W. W. RUBEY of the U. S. Geologcal Survey has accepted an appointment as instructor in geology at Yale University, and begins his new work in October.

WALTER A. ENGLISH has recently joined the staff of the Standard Oil Company of California. One June 6th he was married to Miss Lucille Curtis in Los Angeles.

W. C. KITE, of Oklahoma City, spent the summer in Eastern Canada.

ELMER H. FINCH is in Central America where for some months he will be engaged in geological work. His address is Hotel Grace, Guatemala, C. A.

VERNON F. MARSTERS is now located in the Hayes Bldg., 920 Grand Ave., Kansas City. Mo.

LEON J. PEPPERBURG has opened a new office for consulting work in the American Exchange Bank Bldg., Dallas, Texas.

W. Z. MILLER discovered the Otoe structure for the Gypsy Oil Company.

L. G. HUNTLEY and STIRLING HUNTLEY have opened offices in the Frick Bldg., Pittsburgh, Pa., under the firm name Huntley & Huntley.

K. D. WHITE is in Argentina, S. A. His address is Seccion K, 5 Piso, 560 Avenido de Mayo, Buenos Aires.

FRED B. ELY is engaged in geological work in Europe with headquarters at 82 Avenue de Champs Elysees, Paris.

EDWIN B. HOPKINS has recently returned to New York from a trip to Venezuela and Trinidad.

R. A. CONKLING is Chief Geologist of the newly organized North American Oil Co. (C. F. Colcord) with headquarters in the Colcord Bldg., Oklahoma City.

F. K. FOSTER has resigned from the White Eagle Oil & Ref. Co. to do some special work at the University of Nebraska.

J. G. BARTRAM, of Ardmore, spent his vacation in Colorado.

A. M. MACKENZIE is Chief Geologist of the Mammoth Oil Co., with headquarters at the Teapot Dome camp.

F. B. TOUGH has succeeded A. W. AMBROSE as Chief Petroleum Technologist of the U. S. Bureau of Mines.

LUTHER WHITE is a Director of the newly organized J. A. Hull Oil Co. with headquarters in the Kennedy Bldg., Tulsa.

G. E. ANDERSON, who has been engaged in consulting geology at Fort Worth, will assist PROFESSOR J. B. UMPLEBY at the University of Oklahoma during the present year.

ALEXANDER DEUSSEN was the first geologist to recognize the Mexia fault and he stated in U. S. Geol. Surv., Water Supply Paper 335, 1914, p. 301 that "A fault of small throw crosses the country in a northeast-southwest direction. This fault has broken the continuity of some of the sand lenses that occur in the Navarro formation of the Cretaceous, and it is probable that the gas in the Mexia district is struck in these

discontinuous and locally warped sands on the east side of the fault."

PAUL RUEDEMANN is with COL. M. W. THOMPSON of New York City.

O. B. HOPKINS, Chief Geologist for the Imperial Oil Co. of Canada has returned to the United States, after several months in Peru inspecting the company's holding in Peru, and organizing geological work there.

T. O. BOSWORTH, former Chief Geologist for the Imperial Oil Company, is visiting American oil fields in the interests of a newly organized English oil company.

The Oil and Gas Section of the U. S. Geological Survey now has a permanent representative in the California fields. MR. W. S. W. KEW'S headquarters have been transferred to Los Angeles from Washington.

J. E. BRANTLEY, Geologist for the Atlantic Refining Company, has returned from Mexico and is temporarily located at Shreveport, La., in charge of geological work for the Atlantic Oil Producing Company in Louisiana and Arkansas.

F. J. MILLER is in charge of the geological office of the Texas Company recently reopened at Shreveport, La.

J. B. KERR, formerly with the U. S. Bureau of Mines and co-author with H. W. BELL of a report published by the State of Arkansas on the El Dorado, Arkansas, Oil and Gas Field. is now on the geological staff of the Standard Oil Company of Louisiana with headquarters at Shreveport, Louisiana.

F. X. BOSTICK is paleontologist for the Standard Oil Company of Louisiana with S. C. Stathers, chief geologist, at Shreveport, La.

C. M. BENNETT, vice-president of the Louisiana Oil Refining Corporation and W. C. SPOONER, chief geologist of the Arkansas Natural Gas Company, both of Shreveport, La., made an overland automobile trip in August to the Wyoming and Montana fields.

FRANK A. HERALD, of Tampico, spent his vacation in Tulsa.

A. F. MELCHER, of the U. S. Geological Survey, has devised a hollow bit to break off cores in cable tool drilling.

C. F. BOWEN, Chief Geologist of the Standard Oil Co. of New Jersey, is now in room 322, 26 Broadway, New York City.

J. W. BEEDE has resigned from the Bureau of Economic Geology, at Austin, Texas, to accept a position with the Empire Gas & Fuel Co. at Bartlesville, Okla.

E. W. AMES is engaged in consulting geology at 1302 F. & M. Bank Bldg., Fort Worth, Texas.

A. W. AMBROSE has been appointed Assistant Director of the U. S. Bureau of Mines.

CHARLES ROTH, of the Midwest Refining Co., is Acting Secretary of the Rocky Mountain Association of Petroleum Geologists at Denver.

W. I. ROBINSON reviews the oil and gas possibilities of Michigan in the National Petroleum News for Sept. 6, 1922, with a list of all wells in the state which are reported to have shown oil or gas.

A. B. ROWLEY described the geology of western South Dakota in the Oil Weekly for Sept. 9, 1922. R. A. WILSON described the oil and gas possibilities of the State in Bull. 10, South Dakota geological and Natural History Survey.

GEOLOGISTS working on the Tertiary in any country bordering the Pacific or in the West Indies will find convenient correlations in the proceedings of the First Pan-Pacific Scientific Conference, part 3, published by the B. P. Bishop Museum, Honolulu, 1921.

E. H. SELLARDS issued a press bulletin from the Bureau of Economic Geology about Aug. 25th, describing the geology of Caldwell county and the formations penetrated by the Rios well near Luling. The oil is believed to come from the Edwards limestone.

J. B. BLANCHARD is with the Gulf Production Co. at San Antonio, Texas.

R. D. GOODRICH is now in business for himself.

E. G. SINCLAIR, Divison Geologist for the Midwest Refining Co. at Casper, Wyoming, is making an investigation of the California oil fields.

J. Y. SNYDER discovered the new Arcadia, Louisiana, salt dome. The test of Smitherman et al. in sec. 29, T. 18 N., R. 5 W., encountered rock salt at 1,400 feet and a new test is being started in sec. 20.

S. C. STATHERS discovered the new Bashaway, Louisiana, salt dome in sec. 16, T. 17 N., R. 8 W. The Standard Oil Co., Reese-Jordan No. 1 found the top of the salt dome at 799 feet. The Arkadelphia clay is exposed at the surface.

PAUL B. WHITNEY is with the Inland Oil and Refining Co., at Denver.

C. E. DECKER spent a portion of the summer in Illinois.

A. I. LEVORSEN is in Minnesota.

CLIFTON W. CLARK spent the summer in the Ozarks.

M. J. HOPKINS is Consulting Geologist at Casper, Wyoming.

G. L. HARRINGTON and E. F. BURCHARD, formerly of the U. S. Geological Survey are in Argentina.

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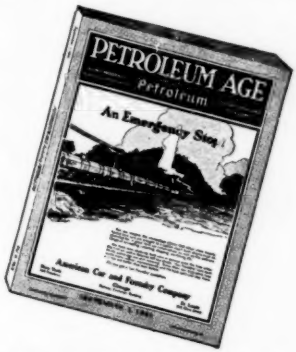

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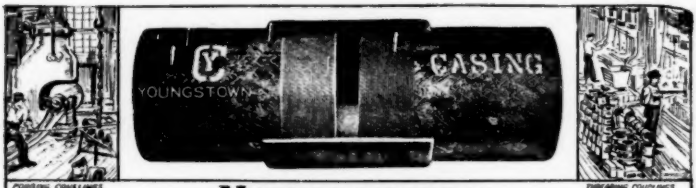

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